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JOURNAL

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ON THE FUNDAMENTAL PRINCIPLES OF THE DIFFERENTIAL CALCULUS.

BY WILLIAM CAIN, C. E., MEM. AM. SOC. C. E.

There are probably no students of the infinitesimal calculus, who have seen its varied applications, that are not impressed with its immense scope and power, "constituting, as it undoubtedly does," says Comte, "the most lofty thought to which the human mind has as yet attained."

It was not to be expected that a science of reasoning, involving so many new and delicate relations between infinitely small quantities, should appear perfect, in its logical development, from the beginning, even with such men as Newton and Leibnitz as its creators. For a long time mathematicians were more concerned in extending the usefulness of the transcendental analysis than in "rigorously establishing the logical bases of its operations," though it has given rise at all times to a great deal of controversy, which has been of great aid to those geometers who concerned themselves particularly with establishing it upon a logical basis. Of this number none are more prominent than the French author, Duhamel. He proceeded by a rigorous use of "the method of limits," whose thorough comprehension he regarded as so important that

he devoted the first half of his Differential Calculus to its numerous applications.

In the United States, after the appearance of Bledsoe's "Philosophy of Mathematics" in 1867, calling especial attention to Duhamel's elegant treatment and contrasting it with the false logic of various other schools, there have appeared a few good elementary books, nearly free from errors, though sometimes showing a trace of them; thus illustrating the tenacious grip of errors induced by early vicious training. With these fairly good books have appeared some as bad as have ever been written, from a logical stand-point, as well as others, where ingenious sophistry has done its utmost to try and blind the student (and possibly the author) to the false logic involved. The English as a rule have followed in the lead of Newton, perpetuating his error that a variable can reach its limit, and they have occasionally introduced a number of errors from the Leibnitz school, whose teachings still pervade most of Germany, the place of its birth.

If the above is true as to the persistent perpetuation of false logic in the treatment of the first principles of the calculus, it would seem that no apology was needed for a critical review of those first principles, particularly as no matter what school is followed in learning the calculus the scientific student will be sure to come across the teachings of various schools in the applications and thus should be prepared to take them at their true worth and modify them in statement or otherwise when necessary.

Although a good deal of old ground is gone over, it was essential to do so to bring out the points criticized in strong relief. The grouping of subjects is intended to be such as to enable the beginner in the calculus to see at once its truth and to catch on to its true spirit. The methods of Newton and of Leibnitz, with criticism, is given in fine print to avoid confusion, and can be omitted the first reading, without detriment to the rest, if preferred.

Definition of the Limit of a Variable. When a variable magnitude takes successively, values which approach more and more that of a constant magnitude, so that the difference with this last can become and remain less than any designated fixed magnitude of the same species, however small, whether the variable is always above or always below or sometimes above and sometimes below the constant, we say that the first *approaches indefinitely* the second and that the constant magnitude is the limit of the variable magnitude.

More briefly, this is often stated thus: The limit of a variable is the constant, which it indefinitely approaches but never reaches.

Definition of an Infinitesimal. An infinitely small quantity or an infinitesimal, is a finite quantity whose *limit* is zero. Hence the infinitesimal approaches zero indefinitely, but can never attain it, since zero is its "limit." As an illustration, take two straight lines incommensurable to each other. Mark the ends of the first line A^1, B^1, the ends of the second A, B. Now as we can always find a unit of measure that will go into A^1B^1 an integral number of times, apply such a unit to AB from A to C, as many times as possible, leaving a remainder over CB less than one of the parts. Then the ratio,

$$\frac{AC}{A^1B^1}$$

is less than the ratio of the two lines, but approaches it indefinitely as the unit of measure decreases indefinitely, since CB being always less than the unit, tends towards zero but can never reach zero; hence CB is an *infinitesimal* and AC approaches AB indefinitely without ever being able to reach it. By the definition therefore, the limit of CB is zero and the limit of AC is AB, hence the limit of the ratio above,

$$\text{lim.}\ \frac{AC}{A^1B^1} = \frac{AB}{A^1B^1}$$

is what is called the incommensurable ratio, $AB : A^1B^1$. It is assumed, of course, that the successive units of measure all exactly divide A^1B^1. It may happen that one of these units applied to AB will cause the point C to lie very near the point B, but for a smaller unit the distance CB will be greater than before, so that the variable CB is sometimes decreasing and then again increasing, but as it is always less than one of the parts into which A^1B^1 has been divided, it can "become and remain" less than one of the parts or less than any finite number that may be assigned, however small; hence zero is its limit by the definition.

If in the ratio above we take A^1B^1 as 1 (one foot say), we have, limit AC = AB from the last equation. AB and AC can thus be regarded as incommensurable and commensurable numbers respectively, and we see from the above that an incommensurable number, as AB, is the limit of a commensurable number as the number of parts into which unity is divided is indefinitely increased.

The student of algebra and geometry is familiar with many applications of the theory of limits, such as: limit of $(1 + \frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \ldots) = 2$, as the number of terms of the series is increased indefinitely; the circle is the limit of a regular inscribed or circumscribed polygon, as the number of sides is indefinitely increased, etc., etc.; so that no more illustrations need be given if these are carefully studied in connection with the first definition given above to show that it is complete and meets fully every case that arises.

It may be observed, too, that although we can express the length of a straight line or the perimeter of a polygon, in terms of the length of a straight line, taken as a unit

of measure, we are confronted with the difficulty, in the case of any curve line, that we cannot apply the unit of measure, or any fractional part thereof, to the curve. We can apply it, however, to the inscribed or circumscribed polygon, and by taking the limit to which these polygons approach indefinitely as the number of sides is increased indefinitely, we get what is called the length of the curve. Similarly no meaning can be attached to the expressions, area of a curve or area of a curved surface, unless we define them as the limit of the area of the inscribed or circumscribed polygon in the first case, or as the limit of the area of the surface of the inscribed or circumscribed polyedrons in the second case, the number of sides or faces, as the case may be, increasing indefinitely. In the case of volumes, too, neither the unit of measure nor any fraction of it can be directly applied when the bounding surfaces are curved, so that a volume must be defined as the limit of the variable volume of some inscribed or circumscribed polyedron as the number of faces is indefinitely increased. The difficulty of measuring curved surfaces, volumes, etc., occurs to every reflecting student, and it is strange that none of our geometries give any definitions but only methods of finding lengths, areas and volumes of curved lines, surfaces and volumes, assuming that the student will find out in some way what is meant by such terms.

The "Theory of Limits" will not be entered into here as it is sufficiently exposed in many text-books. Some strange definitions of infinity, though, appear in some excellent books. The following is a sample: "When a variable is conceived to have a value greater than any assigned value, however great this assigned value may be, the variable is said to become *infinite;* such a variable is called an *infinite number.*" As an "assigned value" means some finite value, it follows from this definition that an infinite number is only some number greater than some

finite number, however large; in other words, an infinite number is a finite number! If such quantities have to be considered they should be given a different name and symbol to avoid confusing these with absolute infinity. The letter G is suggested to distinguish such finite quantities from absolute infinity ∞. We get our ideas of infinity from space and time, for finite as are our capacities, we cannot conceive of space or time ever ending; hence we speak of infinite space and infinite time. However far, in imagination, one may travel in a straight line in space, it is impossible to conceive of ever arriving at any point where there is not *infinite space beyond.* The consideration of a row of figures, 10000 . . . , extended without limit, gives one an idea of an infinite number.

Consider the quotient,

$$\frac{a}{100000} = .00001a,$$

where a is finite.

The number of noughts in the right member is one less than the number of noughts in the denominator, and successive divisions by ten show that the same law holds, no matter how great the denominator.

If we conceive the number of noughts in the denominator to be increased to several billion, the quotient is extremely small, as in the right member we have the same number of noughts less one before reaching the 1; thus as the denominator increases indefinitely the value of the fraction approaches zero indefinitely, and this is all that is meant by the abbreviated notation, $\frac{a}{\infty} = 0$.

Similarly it may be shown, if $\frac{a}{x} = y$ and x decreases

indefinitely, that y increases indefinitely, and this is the meaning of the notation $\frac{a}{o} = \infty$, which has no sense by itself. Although the limit of x above is zero, the limit of y is not infinity, since if y had a limit it could be made to differ from it by as small a quantity as we wish, whereas any finite quantity (y) will always differ from infinity by infinity.

Thus the principle of limits, "if two variables are equal and *each approaches a limit*, their limits are equal," does not apply, as both variables do not approach limits.

Therefore the singular forms mentioned must always be regarded as abbreviations, having the meaning attributed to them above and not as meaning anything in themselves. We have an illustration of such forms in trigonometry. Thus,

$$\tan x = \frac{\sin x}{\cos x}$$

As x approaches 90°, sin x approaches 1, cos x, o, and the left member, though always finite, increases indefinitely. The latter is said to be infinite for $x = 90°$, though strictly, according to the usual definition, there is no tangent of 90°, as the moving radius produced, being parallel to the tangent, can never intersect it. As parallel lines are everywhere the same distance apart, they cannot meet, however far produced, so that the statement that two parallel lines meet at infinity is essentially false.

Similarly we can reason for all the functions that increase indefinitely, without ever ceasing to be finite, where the angle approaches some limit, or fixed value it can never attain, with any meaning corresponding to the functions. The above is still more evident when we regard the ratio definitions first given in trigonometry, for then, there can be no function without a right triangle can be formed and

there is no triangle when one acute angle is either 0 or $90°$; therefore we can only say that $\sin x$ approaches 0 as its "limit" as x indefinitely diminishes, and $\tan x$ increases indefinitely as x approaches $90°$.

With this meaning to be given such expressions as $\sin 0 = 0$, $\tan 90 = \infty$, they can be safely used (and will be used in what follows), though there is really no sine corresponding to $0°$ and no tangent for $90°$.

The next subject treated will be the general one of finding the limit of the ratio of two related infinitesimals, which is the principal problem of the differential calculus.

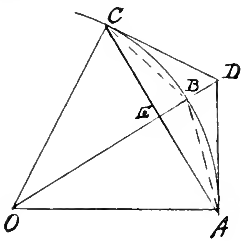

Fig. 1

As a special example, consider the circular arc ABC, fig. 1, of radius unity, whose length in circular measure is $2x$. Divide it into two equal parts, $x =$ AB $=$ AC and draw tangents AD and CD, intersecting on radius OB produced. Call the *chord* AB $=$ *chord* BC $= c$. Then since the radius is taken as unity, EA $= \sin x$ and AD $= \tan x$.

Now by geometry we have,

$$\mathrm{AC} < 2c < 2x < \mathrm{AD} + \mathrm{DC};$$

whence, dividing by 2, we have,

$$\sin x < c < x < \tan x.$$

Also since,

$$\frac{\sin x}{\tan x} = \cos x \therefore \lim. \frac{\sin x}{\tan x} = 1,$$

as x *indefinitely diminishes*, since then, lim. $\cos x = 1$, as $\cos x$ indefinitely approaches unity without ever attaining it.

Now since c and x are always intermediate in value between $\sin x$ and $\tan x$, it follows that the ratio of either to the other, or to $\sin x$ or $\tan x$, approaches indefinitely unity as a limit.

$$\therefore \lim. \frac{\sin x}{c} = \lim. \frac{\sin x}{x} = \lim. \frac{\sin x}{\tan x} = 1,$$

$$\lim. \frac{c}{x} = \lim. \frac{c}{\tan x} = \lim. \frac{x}{\tan x} = 1;$$

and it is the same for the reciprocals of the above ratios.

Any one of the above ratios approaches the form $\frac{0}{0}$ indefinitely, but can never attain it, as the functions cease to exist when $x = 0$ and the ratio ceases to exist; but the constant value which the ratio approaches indefinitely but never attains (*i. e.*, the limit) is at once found to be unity.

A function of x is some expression that contains x and is designated by some letter as f, F, . . . , with x in parentheses following. Thus $f(x)$, $F(x)$, . . . are read little f function of x, large F function of x, etc. If in any function, $f(x)$ of x, the variable x is changed throughout to $(x + h)$ so that the same operations are indicated for $(x + h)$ as in the original function were indicated for x, the result is written $f(x + h)$.

Thus if,

$$f(x) = x^2 \cos\left(\frac{x}{a}\right) + \log x,$$

$$f(x + h) = (x + h)^2 \cos\left(\frac{x + h}{a}\right) + \log (x + h).$$

The increase in x ($= h$), is called the increment of x and is generally written in the calculus Δx, so that $h = \Delta x$. The symbol Δ (delta) indicates a difference, Δx signifying the difference between two states of x and the symbol Δx is regarded as an indivisible one and not composed of two factors Δ and x that can ever be dissociated. Similarly for Δy, Δz, etc., when the letters y, z, etc., occur in any

expression. If $y = f(x)$ and we arbitrarily change x to $(x + h) = (x + \Delta x)$, then y will take a new value, designated by $y + \Delta y$, where Δy is the increase in y due to the increase in x.

Thus, if $y = f(x)$, ---------------------------(1),

$$y + \Delta y = f(x + h) = f(x + \Delta x) \quad \ldots\ldots (2),$$

x is here called the independent variable and y the dependent one, since the value of y depends on that of x, which we shall suppose to increase at will or independently of any other variable in the formula.

It is important to note here that although x is generally increased so that Δx is plus, yet the new value of $y (= y + \Delta y)$ may be either greater or less than before. In the last case Δy will be minus. Hence, if in any case, Δy is found ultimately to be minus, we shall know how to interpret the result.

In equatious (1) and (2), let x be first supposed to have a fixed constant value, then y will have a corresponding constant value. Subtracting (1) from (2) and dividing by Δx,

$$\frac{\Delta y}{\Delta x} = \frac{f(x + \Delta x) - f(x)}{\Delta x} \quad \ldots\ldots (3).$$

We shall presently show that this expression generally has a limit as Δx approaches zero. From (2) above, Δy approaches zero indefinitely at the same time that Δx does, so that (3) approaches indefinitely the form $\frac{0}{0}$, but the *ratio* $\frac{\Delta y}{\Delta x}$ can never reach this form, for where Δy and Δx are both zero there is no ratio. We can however find the *limit*, *or the constant value to which the ratio* $\frac{\Delta y}{\Delta x} = \frac{f(x + \Delta x) - f(x)}{\Delta x}$ *tends indefinitely without ever being able to reach as a ratio*, and this limit is known as the *derivative*, *derived function* or *differential co-efficient of the function* $f(x)$ *with*

respect to x as the independent variable. We have hitherto supposed x to have a constant value, but the above method of finding the derivative is the same whatever value of x, giving real values to y in 0, we start from; hence the method is perfectly general.

As an illustration let,

$$y = f(x) = x^3 + b.$$

If x is changed to $(x + h) = (x + \Delta x)$, y will be changed to $y + \Delta y$.

$$\therefore y + \Delta y = f(x + h) = (x + h)^3 + h.$$

Expanding the right member of the last equation and subtracting the preceding equation from it, we have,

$$\Delta y = 3x^2h + 3xh^2 + h^3.$$

Dividing by $h = \Delta x$, we have,

$$\frac{\Delta y}{\Delta x} = 3x^2 + (3x + \Delta x)\,\Delta x \;.\;.\;.\;.\;.\; (4).$$

The limit to which the right member approaches indefinitely is $3x^2$, since as Δx diminishes indefinitely, so does the term $(3x + \Delta x)\,\Delta x$ in which Δx is a factor. Therefore the derivative of $f(x) = x^3 + b$ with respect to x is,

$$\text{lim.}\,\frac{\Delta y}{\Delta x} = \text{lim.}\,\frac{f(x + \Delta x) - f(x)}{\Delta x} = 3x^2.$$

This limit $(3x^2)$ is true, no matter what value of x we start from, and its numerical value depends upon the value of x. It is seen to be perfectly definite and finite and to vary from zero to plus infinity according as x changes from zero to infinity. For a given value of x as 2, the limit has only one value = 12. Similarly for any other value. It is only in the case of the simpler functions that $f(x + h)$ can be developed readily, so that the derivatives can be easily found, but after *rules* for finding the derived functions of products, powers, etc., have been deduced (as given in elementary treatises on the calculus) the work of finding

them by these rules is comparatively simple, however complicated the functions.

As $\lim. \dfrac{\Delta y}{\Delta x}$, $\lim. \dfrac{f(x+h)-f(x)}{h}$, are cumbersome symbols it is usual to put $\dfrac{dy}{dx}$ for them.

$$\therefore \frac{dy}{dx} = \lim. \frac{\Delta y}{\Delta x} = \lim. \frac{f(x+h)-f(x)}{h}.$$

In this expression dy is read differential of y and dx differential of x, and both dy and dx are to be regarded as indivisible symbols, so that d is not a factor but a symbol of operation. The differentials dy and dx are regarded as finite quantities, whose ratio, for any value of x, is exactly equal to $\lim. \dfrac{\Delta y}{\Delta x}$.

Thus even for the same value of this limit, dy and dx can be supposed to both increase or both decrease at pleasure, the only restriction being that their ratio shall always equal the value of the limit for the particular value of x considered. There is thus great flexibility in this conception of differentials. As a rule we shall consider the differentials as having appreciable values; in other cases it is convenient to treat them as *infinitesimals* or *finite quantities whose limits are zero*, but which consequently never become zero themselves, as then the ratio $\dfrac{dy}{dx}$ has no significance. In the same way Δx and Δy are infinitesimals. In the equation, derived from one above,

$$\frac{dy}{dx} = \lim. \frac{\Delta y}{\Delta x} = 3x^2,$$

it is understood that we can clear the equation of fractions and write,

$$dy = \left(\lim. \frac{\Delta y}{\Delta x}\right) dx = 3x^2 dx.$$

From this equation we see why $3x^2$ (in the particular example) or $\lim. \dfrac{\Delta y}{\Delta x}$ generally, is called a differential co-efficient.

On referring to the right member of eq. (4), we see that *regarded by itself*, it has no limit, since it is an essential requisite that a variable can never reach its limit, whereas by making $\Delta x = 0$, the right member becomes at once $3x^2$; but *considered in connection with the left member*, we see that although Δx must tend towards zero indefinitely, yet it can never be supposed zero, for then the ratio $\Delta y \div \Delta x$ has no meaning. With this restriction, then, the right member can approach $3x^2$ as near as we please without ever being able to reach it; hence $3x^2$ is the true "limit" of the right member when Δx is regarded as an infinitesimal whose limit is zero.

It is evidently immaterial by what law, if any, Δx diminishes towards zero. We can, if we choose, suppose Δx to diminish by taking the half of it, then the half of this result, and so on, in which case Δx will tend indefinitely towards zero, but can never attain it; or we can suppose Δx to diminish, in any arbitrary way, indefinitely towards zero without ever becoming zero. In any case the right member as well as the left has a true limit according to the strict definition.

It is to be observed, too, that this limit is found on the *one* supposition that Δx tends towards zero, for then Δy, as a consequence, tends towards zero indefinitely without ever being able to reach it.

We have emphasized this point, because some of the best known English writers, as Todhemter, Williamson and Edwards, following the lead of

the great Newton, have assumed that a variable can reach its limit, so that (4) above should "ultimately become" $3x^2$.

That Newton failed to establish a true theory of limits is shown in Bledsoe's Philosophy of Mathematics. As it was, he made a great advance over previous methods; but now that a correct theory of limits is so universally known, there can be no excuse for later writers in perpetuating the same errors that seemed inevitable in the dawn of the infinitesimal method. The French writers (following the lead of Duhamel), and also some American writers, have been more logical in their development of the infinitesimal calculus.

The problem of tangents is one which gave rise to the differential calculus and needs to be carefully considered.

In fig. 2, let $y = f(x)$ be the equation of the curve DPS referred to the rectangular axes x and y. Suppose we wish to find the tangent of the angle PEX made by a tangent at a point P of the curve with the X axis or *the slope of the curve at P* whose co-ordinates are x and y. The co-ordinates of a point S to the right of P are $y + \Delta y$, $x + \Delta x$ so that, $PQ = \Delta x$, $SQ = \Delta y$ and,

$$\frac{\Delta y}{\Delta x} = \tan SPR.$$

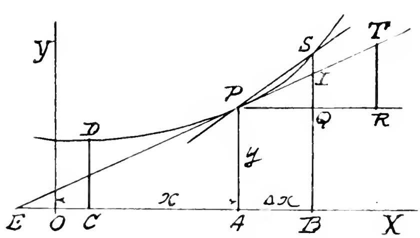

Fig. 2

This equation gives the slope of the secant PS which varies with the values of Δx and Δy. If PS regarded as a line simply, but not a secant, is revolved around P, in one position only, it coincides with the tangent, where it touches the curve in but *one* point. If it is revolved further, it cuts the curve on the other side of P whether the curve in the vicinity of P is convex to the X axis as drawn or concave. If the curve is convex on one side of P and concave on the other, the line PS will cut the curve in three points when it lies

on one side of the tangent, and in one point when it lies on the other side of the tangent. When it coincides with the tangent it cuts the curve in but one point.

But in all cases, it must be carefully noted, that the *secant* PS as it revolves about P can approach the tangent PT as near as we choose, but can never reach it; for then it would cease to be a secant; hence the tangent is the limiting position of the secant. Therefore as Δx (and consequently Δy) diminish towards zero indefinitely, the point S will approach the point P indefinitely and angle SPR approaches indefinitely angle TPR as its limit; whence *tan* SPR approaches indefinitely tan TPR as its limit.

Therefore, taking the limit of the equation above,

$$\lim. \frac{\Delta y}{\Delta x} = \frac{dy}{dx} = \tan \mathrm{TPR} \quad . \; . \; . \; . \; (5).$$

Hence if $y = f(x)$ is the equation of the curve, the derivative of $f(x)$ with respect to x is always equal to the slope of the curve at the point (x, y) considered. Thus the tangent of the angle made by the tangent line of the cubic parabola $y = x^3 + b$, already considered, with the axis of x, equals $3x^2$ at the point whose abscission is x.

This value was determined above and its meaning is that for x equal to 0, $\frac{1}{3}$, $\frac{1}{2}$, 1, etc., the slope of the curve is 0, $\frac{1}{3}$, $\frac{3}{4}$, 3, etc., and it increases indefinitely as x increases indefinitely.

In Edwards' Differential Calculus (second edition, 1892, page 20) we read, changing the letters to suit fig. 2, to which the theory applies: "When S travelling along the curve, approaches indefinitely near to P, the chord PS becomes in the limit the tangent at P." In ex. 2, page 21, the author, in getting the final equation, again says: "When S comes to coincide with P," etc. It is plain from these references that this most recent English author considers a variable to actually reach its limit—*a fundamental error* we have exposed above. The chord cannot reach the tangent without ceasing to be a chord, neither can the ratio $\frac{\Delta y}{\Delta x}$ (= slope of chord) reach its limit $\frac{0}{0}$ without the ratio ceasing to exist.

Let us take as another illustration the common parabola

$$y^2 = 2px.$$

When x increases to $x + \Delta x$, y changes to $y + \Delta y$

$$\therefore y^2 + 2y\,\Delta y + (\Delta y)^2 = 2p\,(x + \Delta x).$$

Subtracting the first equation from the second

$$2y\,\Delta y + (\Delta y)^2 = 2p\,\Delta x$$

$$\therefore \frac{\Delta y}{\Delta x} = \frac{2p}{2y + \Delta y}.$$

As Δx approaches zero, Δy tends in the same time towards zero, a limit which neither can attain however. The right member similarly approaches indefinitely the constant $\frac{2p}{2y}$ without ever being able to attain it, which is therefore its limit by the definition. Hence slope of tangent at point (x, y) is,

$$\lim. \frac{\Delta y}{\Delta x} = \frac{dy}{dx} = \frac{p}{y} = \pm\sqrt{\frac{p}{2x}}.$$

From this equation we see that the slope of the tangent varies from plus or minus infinity for $x = 0$ to plus or minus zero for $x = \infty$.

As, $\lim. \dfrac{\Delta y}{\Delta x} = \dfrac{0}{0} = \dfrac{dy}{dx}$,

the dy and dx would appear to replace the zeros in the singular form $\frac{0}{0}$, which gave rise to Bishop Berkeley's witticism that the dy and dx were "the ghosts of the departed quantities Δy and Δx." As we have defined them above, dy and dx are finite quantities, of the same nature as y and x, whose ratio is always equal to the derivative, this ratio being variable when the derivative is variable. As $y = f(x)$ can always be represented by a locus (since for assumed values of x we can compute and lay off the corresponding

values of y) and since $dy \div dx$ represents the slope of the locus at the point (x, y), we can represent dy and dx by the length of certain lines. Thus in fig. 2, from the point of tangency P, draw PR parallel to the axis of x *any* distance from P to R to represent dx and from the point R draw RT parallel to the axis of y to intersection T with the tangent, when RT will represent dy; for then

$$\frac{dy}{dx} = \tan \text{TPR} = \lim. \frac{\Delta y}{\Delta x},$$

as should be the case.

If we choose to make $dx = \Delta x =$ PQ, then $dy =$ QI, which is less than Δy when S is above I, for a convex curve to X, and greater than Δy when s is below, or for a curve concave to X, just to the right of P. It is only in the case where $y = f(x)$ is the equation of a straight line that for $dx = \Delta x$ we have $dy = \Delta y$, for here $\Delta y \div \Delta x$ represents the slope of the line.

Other important formulas can be deduced from fig. 2.

If we call the length of the curve from some point D to P, s, then the increment of the arc PS corresponding to the simultaneous increment Δx of x will be called Δs. Call the length of the chord PS $= c$.

Then we have,

$$\frac{\text{PQ}}{c} = \frac{\Delta x}{\Delta s \dfrac{c}{\Delta s}} = \cos \text{SPQ},$$

$$\frac{\text{QS}}{c} = \frac{\Delta y}{\Delta s \dfrac{c}{\Delta s}} = \sin \text{SPQ}.$$

Now we have seen before that $\lim. \dfrac{c}{\Delta s} = 1$, so that the

middle terms above approach $\frac{\Delta x}{\Delta s}$, $\frac{\Delta y}{\Delta s}$ indefinitely and the right members approach, as their limits, cos IPQ, sin IPQ respectively, as Δx and consequently Δy and Δs approach zero indefinitely without ever reaching it. Hence taking limits and designating lim. $\frac{\Delta x}{\Delta s}$ by $\frac{dx}{dx}$ and lim. $\frac{\Delta y}{\Delta s}$ by $\frac{dy}{ds}$ we have,

$$\lim. \frac{\Delta x}{\Delta s} = \cos \text{TPQ} = \frac{dx}{ds} \ldots (6)$$

$$\lim. \frac{\Delta y}{\Delta s} = \sin \text{TPQ} = \frac{dy}{ds} \ldots . (7).$$

These equations are satisfied by representing ds by the hypotenuse of the right triangle of which dx and dy are the other two sides. Thus if PQ $= dx$ and QI $= dy$, then PI $= ds$; but if PR $= dx$ and RT $= dy$, then PT $= ds$.

In any case, we have the fundamental relation,

$$ds^2 = dx^2 + dy^2 \ldots .. (8).$$

It is usual to represent the derivative of $f(x)$ with respect to x by $f^1(x)$.

$$\therefore \lim. \frac{\Delta y}{\Delta x} = f^1(x) = \frac{dy}{dx}.$$

If we call w an infinitesimal that tends towards zero in the same time as Δx, we can write,

$$\frac{\Delta y}{\Delta x} = f^1(x) + w \ldots .. (9),$$

for taking the limits of both sides, we reach the preceding equation. The variable w is indeterminate and may be plus or minus. Clearing of fractions, we have,

$$\Delta y = f^1(x)\,\Delta x + w\,\Delta x \ldots . (10).$$

In fig. 2, since $f^1(x)\,\Delta x = \Delta x$ tan IPQ $=$ IQ, we see that the term $w\,\Delta x$ must represent IS.

Comparing the last equation with

$$dy = f^1(x)\,dx,$$

obtained from an equation above, we see that when $dx = \Delta x$,

$$dy = \Delta y - w dx.$$

Thus we have proved analytically, when $dx = \Delta x$ that dy is never equal to Δy (except when $f(x)$ represents a straight line) and the difference is exactly represented on the figure by the distance IS.

Many of the older writers, following the lead of Leibnitz, assumed that dy and Δy, as well as ds and Δs, were identical when $dx = \Delta x$, and the error is perpetuated to this day by possibly the majority of the most recent writers; thus Williamson, in his Differential Calculus (6th Ed., 1887), page 3, says, "When the increment or *difference* is supposed *infinitely small* it is called a *differential*." Similarly in a recent American treatise on the calculus by Bowser, the same definition is given.

Professor Bowser defines "consecutive values of a function or variable as values which differ from each other by *less than any assignable quantity*." He then adds, "A differential has been defined as an infinitely small increment or an infinitesimal; it may also be defined as the *difference between two consecutive values* of a variable or function."

As there are an infinite number of values lying between o and "any assignable quantity," however small, it follows that such differentials are simply *quite small finite* quantities.

The differentiation of a function, as $y = ax^2 + b$, would then proceed after the method of Leibnitz, as follows:

$$y = ax^2 + b.$$

Give to x and y the simultaneous infinitesimal increments dx and dy,

$$y + dy = a\,(x + dx)^2 + b.$$

Subtracting the first equation from the last, we have,

$$dy = a\,(2\,xdx + dx^2).$$

Now from the nature of infinitesimals, it is regarded by the followers of Leibnitz as evident that dx^2 can be neglected in comparison with $2\,xdx$, because the square of the infinitesimal dx is infinitely small in comparison with the variable itself, whence,

$$dy = 2\,ax\,dx.$$

It is scarcely necessary to remark to the reader that, for an *exact* result, we cannot make $dx = 0$ in part of an equation without making it zero throughout; so that the equation is fundamentally wrong.

When we go to the applications to curves, however, another error is made, of an opposite character to the first, so that by this secret compensation of errors the result is finally correct. Thus a curve is regarded as a polygon whose sides connect "consecutive points" and a tangent line

at any point is the chord produced through this point and its "consecutive point," so that $dy \div dx$ gives the slope of the tangent at the point. This is of course wrong, but it exactly balances the other error above, for from the last equation we find the slope, so determined for the curve $y = ax^2 + b$, to be $(2\,ax)$, which we know to be correct by the strict method of limits.

The great French author, Lagrange, says in this connection, "In regarding a curve as a polygon of an infinite number of sides, each infinitely small, and of which the prolongation is the tangent of the curve, it is clear that we make an erroneous supposition; but this error finds itself corrected in the calculus by the omission which is made of infinitely small quantities. This can be easily shown in examples, but it would be, perhaps, difficult to give a general demonstration of it."

Bishop Berkeley, long before Lagrange, showed this secret compensation of errors in a particular example, his endeavor being particularly to "*show how error may bring forth truth, though it cannot bring forth science.*"

Leibnitz, in attempting a defense of his theory, stated that "he treated infinitely small quantities as *incomparables*, and that he neglected them in comparison with finite quantities 'like grains of sand in comparison with the sea'; a v.ew which would have completely changed the nature of his analysis by reducing it to a mere approximative calculus." See Comte's Philosophy of Mathematics, Gillespie, p. 99.

The demonstration given above in the case of $f(x) = ax^2 + b$ can be made general, as follows:

From the exact equation (9) above, following the notation of Leibnitz where dy and dx are taken as identical with Δy and Δx, we have exactly,

$$\frac{dy}{dx} = f^1(x) + w.$$

The followers of Leibnitz, in differentiating, throw away the term w as nothing and pretend to write exactly,

$$\frac{dy}{dx} = f^1(x);$$

but as they make another error by calling the ratio of the *increments* dy and dx the slope of the curve, we thus find the latter to equal $f^1(x)$, which was assumed above to equal $\lim. \dfrac{\Delta y}{\Delta x}$ or the slope of the curve; so that the two errors, for any function, balance each other and we reach a correct result.

As the truth of any result, as given by the Leibnitz method, can only be tested, in a similar manner to the above, by comparing with a result known to be correct by use of the method of limits, it would seem to be inexcusable not to found the calculus upon this latter method. After-

wards a true "infinitesimal method" can be easily logically deduced (as Duhamel and others have shown) that will offer all the advantages and abbreviated processes of the Leibnitz method, with none of its errors of reasoning.

It is well to remark just here that because $y = f(x)$ can always be represented by a locus, and since its derivative with respect to x represents the slope of the tangent at the point (x, y), it will generally be finite. It is only at the points where the tangent is parallel or perpendicular to the axis of x that the derivative is zero or infinity. *Hence the ratio of* Δy *to* Δx, whose limit is the slope, *has generally a finite limit.*

We have studied now, with some thoroughness, the theory of tangents and will next take up, a no less important subject, *the method of rates.* When a variable changes so that, in consecutive equal intervals of time, the increments are equal, the change is said to be *uniform;* otherwise variable. For uniform change, the increment of the function in the unit of time is called the *rate.* Thus in the case of uniform motion, velocity $= \text{rate} = \dfrac{\text{space}}{\text{time}}$.

For a variable change, the rate of the function at any instant is what its increment would become in a unit of time if at that instant the change became uniform.

In looking for an illustration to show clearly the spirit and method of the calculus, perhaps none is more satisfactory to the beginner than the consideration of falling bodies in vacuo. If we call the space in feet, described by the falling body in t seconds, s and g the acceleration due to gravity, we have the relation between the space and time, as given by numerous experiments, expressed in the following equation,

$$s = \tfrac{1}{2} g t^2;$$

Fig. 3

g is a variable for different latitudes and is slightly over 32. Take it 32 for brevity.

$$s = 16\,t^2 \;\ldots\ldots\; (11).$$

In the time $t + \Delta t$ the space described would be $s + \Delta s$ (see fig. 3), and by the same law,

$$(s + \Delta s) = 16\,(t + \Delta t)^2.$$

Subtracting the preceding equation and dividing by Δt,

$$\frac{\Delta s}{\Delta t} = 16\,(2t + \Delta t).$$

This gives the average rate or velocity with which the small space Δs is described.

As the rate or velocity is changing all the time, call v_1 and v_2 the least and greatest values of the velocity in describing the space Δs; then the spaces which would have been described with uniform velocities v_1, v_2 in time Δt are $v_1\,\Delta t$ and $v_2\,\Delta t$, which are respectively less and greater than the actual space Δs.

Hence v_1, $\dfrac{\Delta s}{\Delta t}$ and v_2 are in ascending order of magnitude. As Δt (and Δs consequently) is diminished indefinitely, these three quantities approach equality and the exact velocity the body has at the beginning of the space Δs is given by the constant to which they approach indefinitely but never attain. But lim. v_1 = lim. v_2 = limit $\dfrac{\Delta s}{\Delta t}$ = velocity or rate at the instant the space s has been described (see Edwards' Differential Calculus).

Hence in the particular example above, the *velocity* the falling body has, at the end of t seconds, when it has described the space s, is,

$$\frac{ds}{dt} = \text{lim.}\,\frac{\Delta s}{\Delta t} = 32t \;\ldots\ldots\; (12);$$

i. e., the body at the end of 1, 2, 3 . . , seconds is moving with a rate of 32, 64, 96 . . , feet per second. The same conclusion follows if we give a decrement to t in eq. (11). Thus

$$(s - \Delta s) = 16\,(t - \Delta t)^2$$

$$\therefore \text{lim.} \frac{\Delta s}{\Delta t} = \text{lim. } 16\,(2t - \Delta t) = 32t.$$

The average velocity in describing the space Δs just above the point considered is $16\,(2t - \Delta t)$, that below, as found above, is $16\,(2t - \Delta t)$; the true velocity lies between them and is equal to the limit $16\,(2t)$ of either.

The above general demonstration can be adapted to the rate of increase of any function, $u = f(t)$, which does not change uniformly with the time, u representing a magnitude of any kind, as length, area, volume, etc.; for if Δu is the *actual* change of the magnitude in time Δt, and r_1 and r_2 the least and greatest values of the *rate of change* of u in the interval Δt, corresponding to the increments $r_1\,\Delta t$, $r_2\,\Delta t$, of the magnitude, if these rates were uniform for the time Δt, then $r_1\,\Delta t$, Δu and $r_2\,\Delta t$ are in the ascending order of magnitude; also r_1, $\frac{\Delta u}{\Delta t}$ and r_2 are in the same order. Hence, as these quantities approach equality indefinitely as Δt tends towards zero, the limit of any one of them is equal to the actual rate of increase of the magnitude u which is thus represented by lim. r_1, = lim. r_2, or,

$$\text{lim.} \frac{\Delta u}{\Delta t} = \frac{du}{dt}.$$

Thus the derivative of *any* function, which varies with the time, with respect to t, gives the *exact* rate of increase of the function at the instant considered.

If u and x are both functions of t, connected by the relation $u = F\,(x)$, then

$$\frac{du}{dx} = \frac{\frac{du}{dt}}{\frac{dx}{dt}} = \frac{\text{rate of change of } u}{\text{rate of change of } x}.$$

As an illustration, find the rate at which the volume u of a cube tends to increase in relation to the increase of an edge x, due to a supposed continuous expansion from heat.

$$u = x^3 \therefore \frac{du}{dx} = 3x^2.$$

Therefore for $x = 1, 2, 3$, the volume tends to increase at a rate 3, 12, 27 times as fast as the edge increases. Numerous examples could be given of the application of the differential calculus to the ascertaining of relative rates, but the above will suffice to illustrate the principle.

It has been shown above that if $u = f(t)$, $\frac{du}{dt}$ represents the rate of change of u, if at any time t, the rate is supposed to become uniform; hence du represents what the increment of u would become in time dt.

As time must vary uniformly, dt is always a *constant*, though it is entirely arbitrary as to numerical value; hence the *differential of a variable can be defined, as what the increment of the variable would become in any interval of time if, at the instant considered, the change becomes uniform or the rate becomes constant.* If u is a function of several variables, then the differentials of each must be simultaneous ones, corresponding to the same interval of time.

Newton, in establishing his calculus of fluents and fluxions, conceived a curve to be traced by the motion of a point, an area between the axis of x, the curve and two extreme ordinates, to be traced by the motion of a variable

ordinate to the curve and a solid to be generated by the motion of an area.

As a point traces a curve DPS (fig. 2), when it reaches the point P, it has the direction of the tangent PT at that instant; for we can make only two suppositions: (1) the direction coincides with that of some chord passing through P, whether the other end of the chord precedes or follows P, or (2) it coincides with the tangent; but it cannot have the direction of a chord at the point P without leaving the curve; hence this supposition is false, and as one must be true, it follows that the direction of motion at P must coincide with the tangent PT.

At the point P therefore, by the definition above of a differential, the simultaneous differentials of x, y and s are what their increments would become, during any time, if at P their rates of change should become constant. This can happen only where the motion takes place uniformly along a straight line and this line must be the tangent at P, as that is the direction of motion at that point. The differentials dx, dy and ds can thus be represented by PQ, QI and PI respectively, or by PR, RT and PT, for a uniform increase along the tangent would correspond to a uniform rate horizontally and vertically. This agrees with what has hitherto been established.

The *rates* of increase, horizontally, vertically and along the tangent, are $\frac{dx}{dt}$, $\frac{dy}{dt}$ and $\frac{ds}{dt}$ respectively.

The differential of an area is found as follows: Let area CDPA $= u$, then if $\Delta x = dx =$ AB, $du = ydx$; for although $\Delta u =$ area APSB, the increase of area will not be uniform if the upper end of the ordinate AP moves along the curve, but it will be uniform if it moves uniformly along PQR; for then equal rectangles, as APQB, will be swept out by the ordinate AP as it moves to the right, in equal times.

Therefore by the definition of differential above, $du =$ area APQB $= ydx$. This is readily proved by the method of limits thus: Note that,

$$y\Delta x < \Delta u < (y + \Delta y)\,\Delta x;$$

hence dividing by Δx and observing that as Δx diminishes indefinitely, $(y + \Delta y)$ and hence $\frac{\Delta u}{\Delta x}$ (which is still nearer y) approach y indefinitely in value,

$$\therefore \lim. \frac{\Delta u}{\Delta x} = \frac{du}{dx} = y \quad . \; . \; . \; . \; (11).$$

Similarly we can prove, by either method, that if V represents the volume generated by CDPA revolving about oX, that dV is represented by the volume generated by APQB about OX $\therefore d\text{V} = \pi y^2\,dx$.

Referring to eq. (11) and fig. 2 it is seen that if for any curve $u =$ area CDPA can be expressed as a function of x, or $u = f(x)$, then by the usual notation,

$$\lim. \frac{\Delta u}{\Delta x} = f^1\,(x);$$

and this equals y by (11).

On calling w an infinitesimal that tends towards zero in the same time as Δx, we can write,

$$\Delta u = (f^1\,(x) + w)\,\Delta x,$$

since on dividing by Δx and taking the limit, we are conducted to the preceding equation. But by the Leibnitz method the term $(w\Delta x)$ is thrown away, on differentiating $u = f(x)$, when Δx and Δu are infinitely small, so that $\Delta u = f^1{}_x\Delta x = y\Delta x$.

Another error is made, however, by regarding the area $\Delta u =$ APSB as equal to APQB, which, combined with the preceding result, gives correctly, area APQB $= y\Delta x$. As Leibnitz regarded du and dx as identical with Δu and Δx, when the latter were infinitely small, they should replace the latter in the above equations to express them by his notation.

Thus truth is again evolved from error, and it can be similarly shown in other cases, though a general demonstration seems difficult, if not impossible.

The "Method of Indivisables" by which "lines were considered as composed of points, surfaces as composed of lines and volumes as com-

posed of surfaces, has not been alluded to, as it is not now found in any text-books. It is an exploded theory. Cavalieri, the author, was led to it by noticing, *e. g.*, that in fig. 2, area APQB was never exactly equal to area APSB; hence he made $\Delta x = 0$ and regarded the area Δu as a line AP, so that $u =$ area CDPA was made up of an infinity of lines, etc. This is analogous to the statement that a variable can reach its limit.

In conclusion, let us hope that soon, the false conceptions concerning the fundamental principles of the calculus may be eliminated from all text-books. The world is still waiting for the treatise on the calculus that is simple and clear and at the same time rigorous in its logic.

REMARKS ON THE GENERAL MORPHOLOGY OF SPONGES.*

BY H. V. WILSON.

I have shown† that in Esperella and Tedania the subdermal cavities, canals and chambers develop as separate lacunæ in the parenchyma or mes-entoderm of the attached sponge, subsequently becoming connected into a continuous system. As regards the development of the canal system such varying accounts are given by different authors that were it not for the help lent by comparative anatomy it would be quite impossible to form any idea of the fundamental morphology of sponges. Fortunately for the student entering this puzzling domain comparative anatomy has, in the hands of Haeckel, Schulze and Polejaeff, provided a stand-point from which the varying phenomena of

*These remarks were originally written as part of a paper on the embryology of sponges, which it is expected will soon go to the press. It has not been found possible to insert in the present text the wood-cuts with which the intention was to illustrate many of the facts referred to. The omission of the cuts, while it is to be regretted, will not be found to interfere with the intelligibility of the views expressed.

†Notes on the Development of Some Sponges. Journal of Morphology, Vol. V, No. 3.

development and structure may be viewed with at least a partially understanding eye. It may be that an increasing accumulation of facts will show that Haeckel's conception of the relation of the simple calcareous sponges to the complex horny and silicious forms is not well founded, and that Schulze's view of the parts played by the embryonic layers in producing the adult anatomy is not the true one. But at present it is only with the aid of these theories that one can form any clear conception of the sponges in general, and so provisionally at least we are bound to accept them.

Comparative anatomy points in no undecided manner to the phylogenetic path along which sponges have developed, and so permits us to construct a standard of ontogeny, with which we may compare the actual development of each species as we witness it to-day, and so be enabled to note the amount and kind of divergence (coenogeny) exhibited. That coenogeny is exhibited to a great degree in the embryology of sponges is evident from the various types of development described, and in the future much may be hoped from the study of a group like this for the understanding of the laws of development. For the present all we can do is to accept what seems the most probable phylogeny, recording the instances of supposed coenogeny as they are observed. Adopting this method, I have to regard the development (*i. e.*, the later development or metamorphosis) of Esperella and Tedania as far removed from the phylogenetic path. Before pointing out the features in which the development of these sponges is so strongly coenogenetic, it will be worth while to review briefly the evidence on which rests the current view of sponge morphology.

Evidence from Comparative Anatomy as to Sponge Phylogeny. The strongest evidence offered by comparative anatomy lies in the series of forms, passing by gradations

from very simple to complex types, found in the calcareous sponges,* and in the little group of silicious sponges, the Plakinidæ, described by Schulze.† A comparison of these forms goes to show that the simplest Ascon sponge (Olynthus) must be regarded as the ancestral type of the group, and that by the continued folding of the wall of this simple form were produced the more complicated sponges. Further, the exceedingly complex silicious and horny sponges must be interpreted as colonies in which the limits of the individual can in many cases no longer be recognized.

The calcareous sponges offer a series of increasingly complex forms, which Haeckel divided into Ascons, Sycons and Leucons. Haeckel's views on the relationship of these forms must in great measure be accepted to-day, though in certain respects, especially as regards the anatomy of the Leucons, later researches (Polejaeff, *l. c.*) have shown that he was not always in possession of the real facts of the case.

The simplest calcareous sponges, or Ascons, which serve as the basis for Haeckel's hypothetical sponge ancestor, the Olynthus, are too familiar to call for any description. The interesting form, *Homoderma sycandra* (von Lendenfeld) may, however, be mentioned, in which the body is surrounded by radial tubes, after the fashion of a Sycandra, but with this difference: The central cavity as well as the radial tubes is lined with collared cells. A figure of this interesting sponge is accessible in Sollas's article on Sponges in the Encyclopedia Brittannica, or in the Zoological Articles by Lankester, etc., page 40.

Homoderma bridges the way from the Ascon type to the simplest Sycons, in which the radial tubes are distinct from one another. A surface figure of such a Sycon (*Sycetta*

*Haeckel, Kalkspongien. Polejaeff, Challenger Report on the Calcarea.

†F. E. Schulze, Die Placiniden, Zeit. fur Wiss. Zool. Bd. 34.

primitiva) is given in Vosmaer.* In the majority of Sycons, however, the radial tribes are not distinct, but are connected together more or less by strands of mesoderm covered with ectoderm. The complicated ectodermal spaces thus formed, which lie between the radial tubes, are known as intercanals. Water enters the intercanals through the openings in the surface (surface pores) and passes into the radial canals through the openings in their walls (the primitive pores—so-called chamber pores). The embryology of the Sycons, as far as known, confirms the belief that they are derived from the Ascons. Thus *Sycandra raphanus* passes through a distinctly Ascon phase, the radial tubes appearing later as outgrowths. The actual development of complicated intercanals, such as those just mentioned, has never been witnessed, but the comparison of a large number of forms in which the connection between the radial canals varies within wide limits makes it pretty certain that they are homologous with the simple ectodermic spaces between the radial tubes of Sycetta. It is exceedingly probable that the actual development of the complicated Sycons will show that the radial tubes are in young stages distinct from one another, and only later become connected together by bridges of tissue so as to form complex intercanals. And so we must at present regard the intercanals as lined with ectoderm.

Coming now to the Leucons, we find that Polejaeff's description of the anatomy of this family accords with their derivation from the Sycons, quite as well as did Haeckel's more imaginative conception of the structure of these forms. Taking one of the simplest of Polejaeff's types, *Leucilla connexiva* (Pl. VI, fig. 1*a*, Polejaeff *l. c.*), let us compare it with a Sycon. Such a form is obviously derived from a Sycon by the evagination of the wall of the

*Vosmaer, Bronn's Klass. and Ordnungen, Spongien, Taf. IX. Schulze, Zeit. fur Wiss. Zool. Bd. 31.

paragastric cavity at certain points. These evaginations give rise to numerous diverticula of the central cavity, which constitute efferent canals. The radial chambers are at the same time thrown into groups, each group opening into one of the new diverticula. The intercanals penetrate as before between the several radial chambers, bringing water to the chamber pores, the complexity of their arrangement naturally being increased by the folding of the wall of the paragastric cavity.

The increasing complexity in the Leucon family is brought about by the ramification of the primitively simple efferent canals, the radial tubes growing shorter and becoming in the most complicated types spheroidal chambers quite like the flagellated chambers of the non-calcareous sponges. In *Leucilla uter*, for instance (Polejaeff, Pl. VI, fig. 2*a*), the efferent canals exhibit branching of a simple character. But in such a form as *Leuconia multiformis* (Polejaeff, Pl. VI, fig. 3*a*) the ramification of the efferent canals becomes exceedingly complex, and the radial tubes here appear as spheroidal flagellated chambers. The intercanals (or afferent canals, as they are called in all sponges but the Sycons) follow the efferent canals in all their windings, bringing water from the surface pores to the pores in the walls of the flagellated chambers.

The chief conclusions to be drawn from this anatomical comparison of the various forms of Sycons and Leucons are that the afferent canals of Leucons are homologous with the intercanals of Sycons and are lined with ectoderm; that the flagellated chambers are homologous with the radial tubes; that increasing complexity is brought about by the ramification (or folding of the wall) of the efferent canals.

The canal system of a complicated Leucon, like Leuconia, is essentially like that of a common silicious or horny sponge (having flagellated chambers, afferent and

efferent canals) except in the one respect that in the Leucon there is a single central cavity opening by a terminal osculum, while in most silicious and horny sponges there are several orcula leading into as many spacious efferent cavities. But here the disposition of the calcareous sponges to form indubitable colonies helps us out, for if we compare the silicious or horny sponge with a colony of Leucons instead of with a single one, we find that its derivation from such simple symmetrical forms is made easy. We must suppose the complex non-calcareous sponge to be a colony, in which the limits of the individuals have been lost or obscured by the increasing thickness of the walls. This increasing thickness would finally result in a more or less complete fusion of the members of a colony into an undivided mass with oscula scattered over the surface. Each of the main efferent canals of the non-calcareous sponge is homologous with the paragastric cavity of a single Leucon. Both the canal and its set of branches, though, are extremely irregular, having completely lost the symmetry of the ancestral type. The flagellated chambers still bear the same relation to the efferent canals as they did in the Leucon; *i. e.*, they are simple diverticula of the canals. The system of afferent canals is obviously homologous with the same system in the Leucons, bearing identically the same relation as in the latter group both to the flagellated chambers and the efferent canals. The subdermal cavities (which are only modified portions of the afferent canal system), communicating with the exterior by numerous pores, though a late acquisition, are found in certain Leucons; *e. g.*, Eilhardia Schulzei (Polejaeff, Pl. IX).

In many of the Non-calcarea the colonial nature of the sponge is indicated by the presence of elevations (oscular tubes or papillæ), bearing oscula on their summits. But the number of oscula is not always to be taken as indicating the number of individuals of which the sponge is com-

posed, for the colonies of calcareous sponges show plainly that the budding individuals do not always develop oscula. And on the other hand, there are certain indications in the silicious sponges that in the adult oscula may be developed almost anywhere. In spite of the difficulties, however, in fixing upon the limits of the component individuals the higher sponges are best regarded as colonies. Perhaps the nearest approach made in other groups to the formation of such colonies, in which the personality of the component individual is so nearly lost, is found in corals like Maeandrina, in which the united gastric cavities of the polyps form continuous canals perforated at intervals by mouths.

We therefore reach the conclusion that the higher sponges (non-calcareous) have been derived from colony-producing, symmetrical forms, in which the evaginations of the primitive paragastric cavity had already taken the form of efferent canals and flagellated chambers; that is, from forms allied to the existing Leucons. And we further come to the conclusion that the subdermal cavities and afferent canals are homologous with the intercanals of Sycons, and hence phylogenetically, at least, are infoldings of the ectoderm. The whole efferent system (canals and flagellated chambers both), on the contrary, is homologous with the same system in the calcareous sponges, and is endodermic.

This conclusion as to the parts played by the germ layers in producing the adult non-calcareous sponge, is the one enunciated by Schulze in his classical paper on the Plakinidæ (p. 438). In this little family of silicious sponges Schulze finds a genus, Plakina, the three species of which form links in a chain of increasing complexity, showing quite as clearly as did the calcareous sponges that the afferent system is derived from ectodermal infoldings, and the efferent from endodermal outfoldings.

The Plakinidæ are Tetractinellids. The three species of the genus Plakina are small encrusting sponges found in

the Mediterranean, on the under side of stones, shells, etc. In the simplest species, *P. monolopha*, there is a continuous basal cavity crossed by strands of tissue. From the cavity run more or less vertical efferent canals, which are simple or very slightly branched, and into which open the flagellated chambers. The afferent canals are spacious cavities opening on the surface by wide mouths. The periphery of the sponge forms a continuous rounded rim, the "ringwall," and the oscula, one or several, are situated here. The surface of the sponge inside the "ringwall" is divided up into low rounded elevations, caused by the upper ends of the efferent canals, between which lie the wide apertures leading into the afferent canals. Schulze was fortunately able to observe the main features in the development of this interesting form. There is a solid swimming larva which settles down, forming a flat circular mass. A central cavity appears in the mass, the lining cells becoming columnar, and the sponge is thus transformed into a flat, three-layered sac, the three layers being respectively ectoderm, mesoderm, entoderm. The flagellated chambers appear in a single layer round the central cavity into which they open. They are very probably formed as diverticula of this cavity. Schulze did not follow the development further, but a comparison of the adult with the sac-like young form makes it pretty certain that the young form undergoes a process of folding, which gives rise to the efferent and afferent canals of the adult; or, in other words, the efferent canals arise as vertical evaginations of the sac-like stage. The afferent canals are consequently to be regarded as lined with ectoderm.

In the other two species (*P. dilopha* and *P. trilopha*) the oscula are not situated at the periphery as in *P. monolopha*, but at some distance internal to it; and the efferent canals do not form projections on the surface as in the first species. A comparison of the canal systems makes it evident that

P. dilopha has been derived from *P. monolopha* by an increase in the thickness of the mesoderm lying beneath the surface of the sponge. The wide afferent canals of *P. monolopha* become transformed into the narrow afferent canals of *P. dilopha.*

Plakina trilopha goes a step farther in the direction of complexity than does *P. dilopha.* It has probably been derived from the latter species by the appearance of secondary folds in the radial efferent tubes; by the transformation of the basal cavity into a system of lacunæ, owing to the increase in the number of the connecting strands of tissue between the basal layer and the part of the sponge containing the flagellated chambers; and by a complication in the afferent canals in consequence of which they do not open each by a single aperature, but by a number of small apertures the surface pores.

Schulze's conclusion that these species all lie in one line of descent—that is, that the second species has been derived from the first, and the third from the second—receives as much support from a study of the spicules as of the canal system, but here reference will have to be made to the paper.

From comparative anatomy, then, we conclude the phylogeny of the sponges to be something as follows: The Olynthus is the ancestor of the group. The outgrowth of radial tubes gave rise to the Sycon type. The growth of the mesoderm and development of new endodermic diverticula, coupled with the metamorphosis of the radial tubes into flagellated chambers, produced the Leucons. The non-calcareons sponges have been derived from types more or less like the Leucons. And the conclusion with regard to the germ layers is that the efferent system is entirely endodermic, and the afferent system entirely ectodermic.

Embryological Evidence. Let us see now how far the known facts of development support the above conclusions.

The evidence from the calcareous sponges (Sycandra passes through Olynthus stage) has already been given. Several of the non-calcareous sponges (*Oscarella lobularis*, *Reniera filigrana*, *Chalinula fertilis*, *Plakina monolopha*) run through a stage known as the rhagon (Sollas), which it is permissible to regard as the ontogenetic representative of the Sycon type.

The rhagon of Oscarella* is a three-layed sac with a terminal osculum. The flagellated chambers form a single layer round the central cavity opening into it by wide mouths, and opening on the surface by pores. Regarding this form, as seems best, as equivalent to the Sycon type, it will be noticed that the radial tubes of the Sycon are coenogenetically replaced by flagellated chambers. The rhagon of Oscarella is formed as an invaginate gastrula, which attaches mouth down. The gastrula mouth closes and the osculum is a new formation. The flagellated chambers rise as true diverticula from the central cavity. The adult Oscarella, the canal system of which is not far removed from that of *Plakina monolopha*, is very probably formed from the rhagon, by the development in the latter of a number of simple diverticula from the central cavity. These diverticula are the efferent canals into which open the flagellated chambers. The ectodermic spaces between the efferent diverticula become the afferent canals. The adult Oscarella, like *P. monolopha*, is directly comparable with a simple Leucon. The development of Oscarella, in large measures, confirms the conclusions drawn from comparative anatomy, and may therefore be considered as phylogenetic.

The development of *Plakina monolopha* (Schulze, *l. c.*) has already been described. The sac with its single layer of flagellated chambers round a central cavity is a rhagon, and may be taken as representing the Sycon stage. The adult Plakina itself is the Leucon stage.

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*Heider. Zur Metamorphose der Oscarella lobularis. Arb. Zool. Inst. Wien. Bd. 6.

In *Reniera filigrana** there is a solid swimming larva, which after attaching acquires a central cavity with an apical osculum. The flagellated chambers arise as diverticula from this cavity. Thus in this sponge also there is a rhagon stage. But in one matter we strike upon a coenogenetic modification. The afferent canals instead of being ontogenetically formed from the ectoderm, as they seem to have been phylogenetically, are really formed from endodermic diverticula, which grow outwards, meeting the surface epithelium.

In Chalinula fertilis† there is also a solid larva in which a central cavity is hollowed out. But in this sponge the flagellated chambers of the rhagon stage do not arise as endodermic diverticula, but are formed independently from solid groups of mesoderm cells. This origin of the flagellated chambers must be regarded as coenogenetic. The fact that the mesoderm may take upon itself the function of forming organs ordinarily formed by the entoderm, would seem to indicate that the two layers are of much the same nature. This essential similarity between the two layers has always been maintained by Metschnikoff, not only on the ground of development, but for physiological reasons as well. Thus in young Spongillas when the water became bad he witnessed the entire disappearance of the flagellated chambers, the sponge then consisting of ectoderm and mesoderm alone. With a fresh supply of water the chambers re-appeared.‡ Again, after feeding carmine in an excessive amount to *Halisarca pontica*, he found that the canals and chambers entirely disappeared, the whole body of the sponge inside the ectoderm consisting merely of a mass of amoeboid cells full of carmine (*ibid.*, p. 272).

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*Marshall. Die Ontogenic von Reniera filigrana. Zeit. fur Wiss. Zool. Bd. 37.

†Keller. Stud. uber die Organisation und die Entwick der Chalineen. Zeit. fur Wiss. Zool. Bd. 33.

‡Metschnikoff. Spong. Stud. Zeit. fur Wiss. Zool. Bd. 32.

The development of the afferent system in Chalinula was not worked out with certainty.

The embryology of the preceding sponges in which a rhagon type is developed agrees pretty well with our general notions of sponge phylogeny. But there are other sponges, the development of which has been so excessively modified as no longer to be of any use as finger posts to phylogeny, but which afford an excellent field for the study of what may be called the methods of coenogeny. In *Halisarca Dujardinii* (Metschnikoff, *l. c.*), for instance, there is a solid larva in which the canals appear as so many separate lacunae surrounded by parenchyma (mes-entoderm) cells. The canals only subsequently acquire a connection with each other. In Esperia* the subdermal spaces, canals and chambers arise separately as lacunae in the parenchyma. The chambers are formed from aggregations of small cells in the parenchyma, which Maas believes, on what seems to me insufficient evidence, to be ectoderm cells of the larva that have migrated into the interior. The efferent canals, Maas thinks, are formed from similar cells. In Esperia, according to Yves Delage,† the chambers arise by division of special mesoderm cells. The epithelium of the canals comes from the larval ectoderm, which has migrated into the interior. In Spongilla, according to the same author,‡ the ectoderm cells of the larva are engulfed by mesoderm cells and then become the lining cells of the flagellated chambers. The observations of Delage on these points need to be confirmed before they can be taken as the basis for generalizations.

In young Stellettas§ the subdermal cavities seem to arise

*Maas. Die Metamorphose von Esperia Lorenzi, etc., Mith. aus dem Zool. Sta. zu Neapel, Bd. 10, Hept. 3.

†Sur le developpement des Eponges siliceuses, etc. Comptes rendus. T. 110.

‡Sur le developpement des Eponges (Spongilla fluviatilis). Comptes rendus. T. 113.

§Sollas. Challenger Report on Tetractinellidae, pp. XVI, XVII.

as lacunae in the parenchyma. And in the external buds of *Tethya maza** Selenka believes that the subdermal cavities have a similar origin.

In Spongilla, according to Götte†, the subdermal cavities and canals are formed as independent lacunae in the parenchyma, and the flagellated chambers are formed from groups of cells, each group (and chamber) being produced by the budding of a single large mesoderm cell. This account of the development of these structures in Spongilla, which is not very different from my own for Esperella and Tedania, is contradicted by Maas,‡ who brings Spongilla in line with the forms having a rhagon. Maas describes in the larva a central cavity from which the chambers arise as diverticula, the central cavity persisting in a modified shape as the efferent system of canals. The subdermal spaces arise as ectodermal invaginations, from which the afferent canals are formed as ingrowths. Thus, according to Maas in the ontogeny of Spongilla, the whole afferent system is formed from the ectoderm and the whole efferent system from the endoderm. Ganin's earlier account§ likewise describes the chambers as diverticula from a main endodermic cavity.

In the metamorphosis of a larva which probably belongs to Myxilla, Vosmaer finds that the subdermal cavities begin as fissures which gradually become wider, and that the canals and chambers likewise appear as intercellular spaces. Finally in the gemmule development of Esperella and Tedania, I find that subdermal cavities, both sorts of canals, and the flagellated chambers, all arise as independent lacunae in the parenchyma.

Accepting as ancestral the development of *Oscarella* and

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*Zeit. f. Wiss. Zool. Bd. XXXIII.

†Untersuchungen zur Entwicklungs-geschichte von Spongilla fluviatilis, 1886.

‡Ueber die Entwicklung des Surssvasserschwamms. Zeit. fur Wiss. Zool. Bd. 50.

§Zur Entwicklung der Spongilla fluviatilis. Zool. Anzeiger. 1878.

Plakina monolopha, the various coenogenetic modifications which appear in other sponges may be classified as follows:

1. The efferent canal system, instead of arising as a single cavity which throws out diverticula, may be formed as so many distinct cavities, which subsequently unite (*Esperella*, *Tedania*, *Esperia lorenzi* and *lingua*, *Halisarca Dujardinii*, *Myxilla*).

2. The flagellated chambers, instead of arising as endodermic diverticula, may be formed from groups of mesoderm cells (*Esperella*, *Tedania*, *Chalinula fertilis*, *Myxilla* and probably in *Esperia lorenzi* and *E. lingua*).

3. The afferent canals, including the subdermal cavities, instead of being formed as invaginations from the ectoderm, arise as lacunae in the mes-entoderm (*Esperella*, *Tedania*, *Esperia lorenzi* and *lingua*, *Stelletta*, *Myxilla*). In *Reniera filigrana* they are formed as entodermic diverticula.

The coenogenetic development of the flagellated chambers and efferent canals suggests, as I have said, an essential similarity of nature in the so-called entoderm and mesoderm of sponges. This belief, so long upheld by Metschnikoff, derives some of its strongest support from this author's physiological investigations (see *ante*, p. 10), as well as from the fact first emphasized by Metschnikoff and Barrois, that in the most common sponge larva, *i. e.*, the solid larva, the mesoderm and entoderm form a single indivisible layer.

And likewise the development of the afferent system of canals in some sponges from the ectoderm, in others from the mes-entoderm, may possibly be taken as meaning that even these two primary layers (the outer and the inner) are not distinctly differentiated from each other in the sponges, or, in other words, that the mes-entoderm is still enough like the ectoderm to form organs ordinarily produced by the latter layer.

There is another (hypothetical) way of explaining these phenomena, which consists in supposing that ectoderm cells of the larva migrate into the interior, and though indistinguishable from the surrounding mes-entoderm cells, alone take part in forming the afferent canals. Similarly we may suppose that in the solid mass, which constitutes the parenchyma of Esperella, there are two radically distinct classes of cells, one of which is potentially gifted with the power of forming efferent canals and flagellated chambers, while the other has not the power, and must remain as amoeboid mesoderm. But this is pure hypothesis.

The result of this critical examination seems to be that the Olynthus must be regarded as the common ancestor of sponges (Haeckel, Kalkspongien), and that the entoderm and mesoderm are not sharply differentiated from one another as they are in the higher animals (Metschnikoff, Spong. Studien, p. 378).

Origin of the Olynthus. The prevalence of the solid larva in sponges and Hydromedusæ, coupled with the widespread presence of intracellular digestion in the lowest metazoa, led Metschnikoff years ago to the belief that the solid larva represents the ancestral form of the metazoa, while the gastrula is a coenogenetic modification.* To my own mind all the facts that we know indicate that Metschnikoff's conclusion is well founded. This hypothetical ancestral form is known as the Parenchymella (Phogocytella). I may be permitted to recall its leading features as deduced by Metschnikoff. The animal consisted of an outer layer of flagellated cells and an inner mass of amoeboid cells. The digestion was intracellular, the food being taken in through intercellular openings (pores) scattered over the surface. A central cavity having a special opening to the

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*Metschnikoff. Spongiologische Studien. Zeit. f. Wiss. Zool. Bd. 32. Metschnikoff. Embryologische Studien au Medusen. Wien., 1886.

exterior (osculum) was a later acquisition, the osculum being in all probability one of the small apertures (pores) especially enlarged. Even after the formation of this cavity the division of the parenchyma into entoderm and mesoderm was not (and is not) in the sponges a rigid division, the primitive power of digesting food intracellularly having been retained by both layers. It was only with the appearance of the higher animals that the separation of entoderm from mesoderm became a perfect one. (Spongiologische Studien, p. 378). This solid ancestor of the metazoa, Metschnikoff derives from colonial forms like Protospongia. Barrois as early as 1876* stated his belief that the ancestor of the sponges was a solid animal, composed of two layers, the outer representing the ectoderm, the inner mass representing a parenchyma from which have developed the entoderm and mesoderm of higher animals (p. 78).

According to this view the early development of Plakina (or Reniera, Chalinula, etc.) gives the first chapters in the history of the group of sponges more faithfully than does a form like Oscarella (or Sycandra). In the former sponges it will be remembered there is a solid larva hollowed out to form a three-layered sac, which then breaks open to the exterior, forming the osculum. In the latter there is an invaginate gastrula, which settles mouth downwards, the gastrula mouth subsequently closing and the osculum appearing as a perforation at the upper end of the sac. In these forms (Oscarella, Sycandra) we have to suppose that the Parenchymella stage is skipped, the central cavity (which properly belongs to the Olynthus stage) being precociously developed coincidently with the immigration of the entoderm. The blastopore of the sponge gastrula, on

*Memoire sur l'embryologie de quelques Eponges de la Manche. Ann. Sci. Nat. T. 3, VI Ser.

this view, does not represent a primitive organ (Urmund), but merely comes into existence owing to the special, and highly modified, method of forming the entoderm. We do not, therefore, have to construe the Oscarella development (with Heider and Sollas) as meaning that a gastrula ancestor settled mouth downward, and that the mouth gradually became functionless, finally closing up, while a new series of openings, pores and osculum, were established.

The only remaining point I wish to speak of is the relation of the sponges to the Coelenterates. That the two groups have had a common ancestor in the Parenchymella is highly probable, but the similarity between the Olynthus and the simplest Coelenterates inclines one to go further, and at any rate homologize the paragastric cavity of the former with the gastric cavity of the latter. This, of course, is done by authors like Sollas, who derive both groups from a common gastrula ancestor. Whether the osculum of the Olynthus is also homologous with the gastrula mouth, as Haeckel originally held, is a question which needs for its answer more facts relating to the actual use to which the osculum is put in the simplest sponges. Sollas and Heider urge against the homology the fact that the Coelenterate larva attaches by the pole opposite the blastopore, while in the sponge larva the blastopore is at the pole of attachment. But this I cannot regard as a very strong argument, for (with Metschnikoff) I do not believe that the opening into the gastrula cavity represents a primitive organ (mouth of an ancestor). And if it does not, but is merely an incidental product of a particular mode of entoderm-formation employed by the animal, it has no bearing on the question of homology between osculum and mouth. Consequently the fact that in the attaching coelenterate and sponge larvæ the blastopore is at oppo-

site poles is a curious phenomenon, but one aside from the problem.

I doubt very much, however, if any such radical distinction can be drawn between the larvæ of the two groups, for it is a question whether any sponge larva has a particular pole by which it must attach. Even in Sycandra, Schulze (*l. c.*, p. 270) records that exceptional cases occur, which cannot be regarded as pathological, in which fixation takes place not by the gastrula mouth but on the side. Fixation may also be delayed until the gastrula mouth has closed and spicules have begun to appear, in which case it is not stated by what part the larva attaches. In the solid larvæ of silicious sponges the variation is much greater. Such larvæ attach in some cases by the posterior pole, in others by the anterior pole, and yet in others on the side. All these variations may occur in larvæ of the same species. For instance, Maas records that in Esperia he observed fifteen individuals attach by the posterior pole, seventy individuals by the anterior pole, and five or six on the side. It thus appears that in the larvæ of silicious sponges at any rate there is no constant point of attachment.

University of North Carolina, November 7, 1892.

RECORD OF MEETINGS.

SIXTY-SEVENTH MEETING.

PERSON HALL, January 19th, 1892.

President Holmes in the chair.

1. The Oyster Question. H. V. Wilson.

2. Magnetic Iron Ores of Ashe County. H. B. C. Nitze.

Report of the Secretary. One hundred and twenty-six books and pamphlets received and the following new exchanges:

New York Mathematical Society.

La Société Geologique du Nord du France.

SIXTY EIGHTH MEETING.

PERSON HALL, February 9th, 1892.

Called to order by the President.

3. The Gréenwood Process for the Direct Production of Caustic Soda and Hydrochloric Acid. Chas. Baskerville.

4. The Determination of the Standards of Length. J. W. Gore.

5. Chinese Salt-making. F. P. Venable.

6. The Plan and Limitations of the N. C. Geological Survey. J. A. Holmes.

Report of the Secretary. Seventy-five books and pamphlets received.

New exchange: E. M. Museum of Princeton College.

SIXTY-NINTH MEETING.

PERSON HALL, April 12th, 1892.

Professor Gore presided.

7. Common Roads. Wm. Cain.

8. Igneous Rock Formation of North Carolina. J. A. Holmes.

New exchange: Institut Royal Grand Ducal de Luxembourg.

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JOURNAL

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STATISTICS OF THE MINERAL PRODUCTS OF NORTH CAROLINA FOR 1892.

BY H. B. C. NITZE.

The difficulties attending the collection of exact statistics of the various mineral productions are very great, often insurmountable; and especially difficult to obtain are those of the gold, corundum and mica mines, which form the greater part of North Carolina's mining industry.

The following statistics have been collected from the most reliable sources available, under the direction of the *North Carolina Geological Survey*, and although often lacking in detail they will serve to show very nearly what the mineral production of the State has been for the past year.

Of the metallic products gold and iron stand alone. Under the list of non-metallic products we have iron ore, copper ore, bituminous coal, corundum, mica, talc and kaolin.

GOLD.

During 1892 there were fifty-six gold mines, distributed over eighteen different counties, in operation in the State. Of these, fifteen were placer and forty-one vein workings.

The total number of stamps in operation is estimated at 310, the total amount of labor at 500 men, and the total production at $65,000.

PIG IRON.

There was but one blast furnace in active operation in the State, namely, that at Cranberry, Mitchell county, belonging to the *Cranberry Iron and Coal Company*. This is a small brick stack of the following dimensions: Height 50 feet, diameter of bosh 10 feet 2 inches, diameter of hearth 3 feet, capacity 14 to 15 tons per day. It uses the low phosphorus magnetic ore of the Cranberry mine situated close by, magnesian limestone from Carter county, Tenn., and coke from Pocahontas, W. Va.

The total output of this furnace for 1892 was 2,902 gross tons, of which 313 tons were charcoal and 2,589 tons coke iron; the total product was valued at $52,000 at the furnace.

The quality of this product was a special Bessemer iron, averaging less than 1.00 per cent. silicon, and less than 0.025 per cent. phosphorus. It was shipped to steel works in Ohio and Pennsylvania.

The total production in gross tons (22,401 pounds) of the Cranberry furnace for the past nine years is shown in the following table:

1884.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.
388	1,598	1,964	3,250	2,143	2,587	2,840	3,217	2,902

FORGE IRON.

The small amount of forge iron made for purely local purposes at Pasley's forge, in Ashe county, is rather of historical than commercial interest. This forge is situated at the mouth of Helton Creek, and consists of one fire

blown by the water trompe, and one hammer operated by water-power. It is the only forge now in operation in the State, and makes annually about twenty to thirty tons of bar iron for local uses.

IRON ORE.

The total production of iron ore during 1892 is estimated at 23,433 gross tons, valued at $43,306.20 at the mines. Of this amount 17,088 gross tons, valued at $34,423.20, were shipped out of the State; the balance was turned into 2,902 gross tons of pig metal.

The only two mines in operation were the Cranberry mine in Mitchell and the Ormond mine in Gaston county.

The Cranberry Mine, operated by the Cranberry Iron and Coal Company, produced 18,433 gross tons, valued at $25,806.20 at the mines. Of this amount 12,088 tons, valued at $16,923.20, were shipped to furnaces in Southwest Virginia.

The ore is a magnetite, of which the following analysis by Mr. Porter W. Shimer shows the quality of the run of mine:

	Per Cent.
Silica	23.73
Metallic iron	45.90
Metallic maganese	0.44
Alumina	1.01
Lime	9.69
Magnesia	1.51
Sulphur	0.012
Phosphorus	0.007

The total output of the Cranberry mine in gross tons for the past nine years is shown in the following table:

1884.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.
3,998	17,839	24,106	45,032	15,705	19,819	30,290	27,628	18,433

The Ormond Mine, situated in Gaston county, on the Charlotte & Atlanta Air Line, produced during 1892 about 5,000 tons of ore, valued at $17,500 at the mines. It was shipped to Birmingham, Ala., and Richmond, Va., for the fettling of puddling furnaces.

The ore is a mixture of hard, block hematite, or rather turgite, porous limonite, and soft, black, powder ore, slightly magnetic, of which the following are some representative analyses:

	I.	II.	III.	IV.
Silica	9.72	1.51		1.55
Metallic iron	52.39	65.79	47.10	65.35
Phosphorus	0.079	0.028	0.057	0.007

I. Lump ore; analysis by N. C. Geological Survey.
II. Lump ore; analysis by Carnegie Bros. & Co., Pittsburg, Pa.
III. Limonite; analysis by C. D. Lawton.
IV. Black powder ore; analysis by Carnegie Bros. & Co.

The mine was closed down in September, 1892, on coming into possession of the *Bessemer Mining Company*, which is remodeling the plant and making preparations for a large output in the near future.

The North Carolina Steel and Iron Company completed their furnace at Greensboro in June, 1892. The height of the stack is 70 feet, diameter of bosh 16 feet, and the calculated capacity 100 tons per day. The plant is fully equipped with all modern improvements, and, together with ore lands, town-site lands and other improvements, represents a total investment so far of $305,000. It is now expected to have this furnace in operation by the coming spring, the delay of putting it in blast having been caused by a deficiency of the necessary funds; and the present low price of iron has deterred the company from endeavoring to procure the requisite capital sooner. It is also proposed to erect a merchant mill, machine shops, foundry and car works during this year, the latter to have a capacity of ten (10) freight cars a day. The principal

supply of ore will be obtained from the mines of the company at Ore Hill, Chatham county, about forty miles distant. This ore is a brown hematite of very fair quality, as shown by the following analyses, made in the laboratory of the *North Carolina Geological Survey:*

	I.	II.	III.	IV.
Silica	4.73	2.35	17.32	3.71
Metallic iron	47.87	47.23	42.88	49.79
Sulphur	0.034	0.280	0.230	0.170
Phosphorus	0.069	0.139	0.106	0.038

These deposits have been partially developed during the past year and about 700 tons of ore taken out. Besides this source magnetic ores from the western part of the State will be used. Limestone will be obtained from Virginia and coke from the Flat Top region in the same State.

In *Granville county* some recently discovered deposits of magnetic iron ore of good quality have been prospected with encouraging results, but no regular mining operations have yet been started, and no ore has been shipped.

COPPER ORE.

The Blue Wing Mine in Granville county was the only producing mine in the State during 1892. Up to October, when the mine and concentrator closed down indefinitely, the production of concentrates, shipped to the Orford Copper Works, N. Y., was valued at $15,000 (estimated).

The ore is chiefly bornite in a quartz gangue. The following analyses show the quality of the ore and concentrates:

	Copper. Per Cent.	Silver. Oz. Per Ton.
Run of mine ore	8.66	3.55
Cobbed ore	14.21	5.66
Jig concentrates	52.32	12.00
Frue vanner concentrates	36.87	12.60

COAL.

The *Egypt Coal Company*, operating the Egypt mine in Chatham county, shipped during 1892 6,500 tons of bituminous coal, valued at $7,475. Misfortunes by fire and water cut down the output to nearly one-half of what it was the year preceding. The company has been engaged in improving and increasing its plant during the past year by the addition of three pumps underground and further hoisting capacity. A second shaft, 8 by 12 feet, is being put down, to be used exclusively for ventilating purposes.

The following analysis by the *North Carolina Geological Survey* represents the quality of this coal:

Moisture	1.25
Volatile matter	33.35
Fixed carbon	49.18
Ash	16.22
Sulphur	1.72
Specific gravity	1.294

CORUNDUM.

The total corundum product for 1892 is estimated at 560 net tons. No estimate of the value can be made.

The chief producers were the Corundum Hill and Ellijay mines in Macon, and the Hogback mines in Jackson county. In Iredell county some private prospecting was carried on during the latter part of the year, two miles west of Statesville, and several veins were located, from which about 9,000 pounds of corundum were taken, but no regular operations have as yet been instituted.

MICA.

During 1892 there were in operation some ten or twelve mica mines, situated principally in Mitchell and Yancey counties. The total production of these mines is estimated

at 10,000 pounds of cut mica, valued at about $35,000. The average price of 3 by 5-inch cut mica, at the mines, is put at $3.50 per pound.

During the year three mills, manufacturing ground mica from waste scraps, were in operation in Mitchell county, but no estimate can be made of their output.

TALC.

The total production of prepared talc (shipments from mills) for 1892 is estimated at 2,500 net tons, valued at about $19,000 at the mills.

The two principal producers were *The Notla Consolidated Marble, Iron and Talc Company*, of Cherokee, and *Messrs. Rickard and Hewitt*, of Swain county.

KAOLIN.

The total production of prepared kaolin for 1892 is estimated at 3,900 net tons, valued at $31,200 at the works.

The principal producers were the works at Sylva and Dillsboro, in Jackson county.

ADDITIONS TO THE BREEDING AVI-FAUNA IN NORTH CAROLINA SINCE THE PUBLICATION OF PROF. G. F. ATKINSON'S CATALOGUE IN 1887.

BY J. W. P. SMITHWICK.

1. Great Blue Heron (*Ardea herodias*). Young ones have been seen and taken in all sections.

2. Little Blue Heron (*Ardea cœrulae*). Reported breeding in the west by Mr. John S. Cairns, Buncombe county.

3. Red-tailed Hawk (*Buteo borealis*). One nest containing two eggs was found by myself in Bertie county, 1888.

4. Broad-winged Hawk (*Buteo latissimus*). Breeds in middle and western sections. (Brimley and Cairns).

5. American Sparrow Hawk (*Falco sparverius*). Nests have been found in all sections; I have noted several in the east.

6. American Osprey (*Pandion haliætus carolinensis*). Have noted two nests in Bertie county and seen young ones several times; reported breeding along the larger streams of the west by Cairns.

7. Black-billed Cuckoo (*Coccyzus erythrothalmus*). Reported breeding in Wake county by Brimley; Cairns says that it breeds during some seasons in the mountains.

8. Belted Kingfisher (*Ceryle alcyon*). I found a nest containing seven eggs in 1889, which was placed at the end of a burrow in a bank on the Cashie River near its mouth; breeds in the west. (Cairns).

9. Hairy Woodpecker (*Dryobates villosus*). Said to breed in the higher mountains of the west by Cairns.

10. Yellow-bellied Sapsucker (*Sphyrapicus varius*). Reported breeding by Cairns in Buncombe county on higher mountains.

11. Red-headed Woodpecker (*Melanerpes eryphrocephalus*). Found commonly breeding in all sections.

12. Red-bellied Woodpecker (*Melanerpes carolinus*). Rather rare breeder in all sections of the State.

13. Chuck-will's-widow (*Antrostomus carolinensis*). Three nests, containing two eggs each, were found by myself in Bertie county; one in 1888 and two in 1891.

14. Night-hawk (*Chordeiles virginianus*). Found breeding in the eastern section by myself.

15. Least Flycatcher (*Empidonax minimus*). Reported as a rare breeder in mountains by Cairns.

16. American Crow (*Corvus americanus*). Found breeding in all sections, common.

17. Boat-tailed Grackle (*Quisculus major*). One nest containing four eggs was taken in Plymouth from an old elm overgrown with ivy, in 1889, by myself.

18. Towhee (*Pipilo erythrothalmus*). Reported by Cairns as breeding in Buncombe county.

19. Rose-breasted Grosbeak (*Habia ludoviciana*). Said to breed on craggy mountains by Cairns.

20. White-bellied Swallow (*Tachycineta bicolor*). Several nests containing eggs have been taken by my cousin (T. A. Smithwick) and myself in the last few years.

21. Logger-head Shrike (*Lanius ludovicianus*). Reported breeding in Iredell county by McLaughlin.

22. Warbling Vireo (*Vireo gilvus*). Reported breeding along the rivers in the mountain section by Cairns.

23. Yellow-throated Vireo (*Vireo flavifrons*). I have taken two nests in Bertie county; no others have been recorded.

24. Mountain Solitary Vireo (*Vireo solitarius alticola*). Found breeding in the higher mountains by Cairns.

25. White-eyed Vireo (*Vireo noveaboracensis*). Breeds throughout the State, common.

26. Prothonotary Warbler (*Protonotaria citrea*). I found one nest in 1888 in Bertie county which contained three eggs; this is the farthest north that any nest has been recorded on the Atlantic slope, so far, I think.

27. Worm-eating Warbler (*Helmintherus vermivorus*). One nest was found in Bertie county by T. A. Smithwick and one in Buncombe county by Cairns last spring; this shows that it may breed in all portions.

28. Blue-winged Warbler (*Helminthophila pinus*). Said to breed in the mountains by Cairns.

29. Magnolia Warbler (*Dendroica maculosa*). Breeds in the west; young ones have been seen in July by Cairns.

30. Oven-bird (*Seiurus aurocapillus*). One nest was found in Bertie county in 1892 by myself.

31. Hooded Warbler (*Sylvania mitrata*). I found one nest in 1888, and since that time a great many nests have been found by my cousin and myself in Bertie county. Not reported from any other section.

32. Winter Wren (*Troglodytes hiemalis*). Two nests were found by Cairns on the Black mountains in the spring of 1892.

33. Golden-crowned Kinglet (*Regulus satrapa*). Reported breeding on Black mountains by Cairns.

34. Olive-backed Thrush (*Turdus ustulatus swainsonii*). One nest has been reported, it being found on Black mountains by Cairns.

CONTRIBUTIONS FROM GEOLOGICAL DEPARTMENT UNIVERSITY OF NORTH CAROLINA.
NO. I.

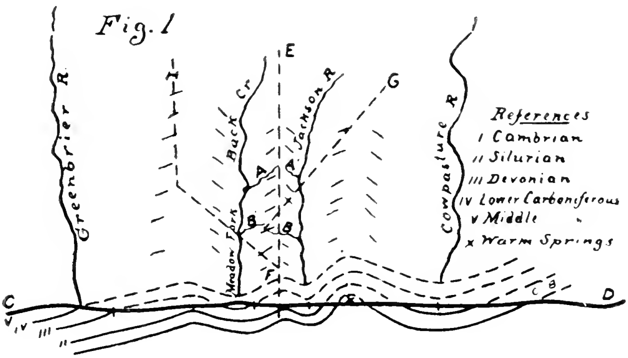
AN EXAMPLE OF RIVER ADJUSTMENT.

BY CHARLES BASKERVILLE AND R. H. MITCHELL.

One could scarcely find an example which more fully illustrates the principles involved in determining the courses of streams than the Jackson River in western Virginia. This is a small stream rising near Monterey, Highland county, flowing south-west through Bath into the James River at Covington, Alleghany county.

The existing topography is the result of the denudation following upon the great Permian deformation, which gave rise to the main ranges of the Appalachians. From

this upheaval dates the beginning of the history of the rivers of this region.



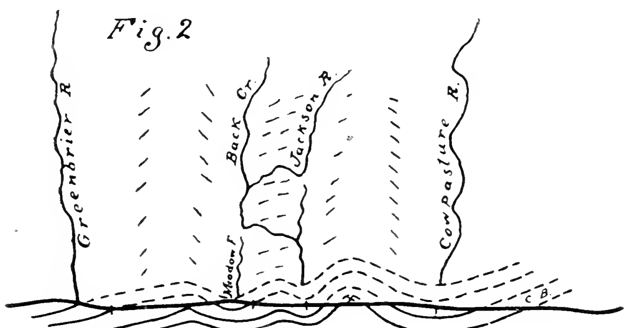


Diagram I gives a rough perspective of this immediate region, together with a vertical section in a north-west and south-easterly direction, just south of Warm Springs. In the vertical section the unbroken lines represent the geological structure of the present topography (heavy line CD) and the dotted lines the same in Permian time. The perspective shows the drainage consequent upon the deformation, and combining the two, it can be seen that the Jackson River flowed down a syncline in a south-westerly direction on a bed of the lower carboniferous rock. Parallel to this, and in a similar syncline on the

same stratum with lower level, flowed now Back Creek, formerly Meadow Fork of the Greenbrier River, West Virginia. Tributary A of Back Creek, on account of steepness of slope, gnaws back, capturing headwaters of Jackson River by tributary A^1, causing the same to have its outlet in a north-westerly direction, thus throwing the water-shed east (GF) between Cowpasture and Jackson Rivers, which previously (EF) was between Jackson River and Back Creek. The base of the syncline, then the bed of Back Creek (Meadow Fork), was nearer base level than base of Jackson River syncline, consequently the softer Devonian slates were reached first by the latter. With conditions thus changed the tributary B of Jackson River captures in turn the headwaters (B^1) of Meadow Fork (Back Creek), and the water-shed (HF) as now exists was shifted west between Greenbrier River and Meadow Fork of same and Back Creek. Diagram II shows the present flow of waters of Jackson River.

UNIVERSITY OF NORTH CAROLINA.

CHARACTER AND DISTRIBUTION OF ROAD MATERIALS.

BY J. A. HOLMES.

In the following discussion of the character and distribution of road material in the State it is thought best to avoid the use of technical terms as far as possible; and the names of rocks here used are those applied by the engineer rather than by the geologist. The character of the materials is discussed with a view to their fitness for use in the construction of broken-stone pavement, as used by Macadam and Telford on the public highways.

CHARACTER OF ROAD MATERIALS.

"In considering the relative fitness of the various materials," says Byrne,* "the following physical and chemical qualities must be sought for:

"(1). Hardness, or that disposition of a solid which renders it difficult to displace its parts among themselves.

"(2). Toughness, or that quality which will endure light but rapid blows without breaking.

"(3). Ability to withstand the destructive action of the weather, and probably some organic acids produced by the decomposition of excretal matters, always present upon the roadways in use.

"(4). The porosity, or water-absorbing capacity, is of considerable importance. There is, perhaps, no more potent disintegrator in nature than frost, and it may be accepted as fact that of two rocks which are to be exposed to frost, the one most absorbent of water will be the least durable."

The following table shows absorptive power of a few common stones:†

	Percentage of Water Absorbed.		Percentage of Water Absorbed.
Granites	0.06 to 0.155	Limestones	0.20 to 5.00
Marbles	0.08 to 0.16	Sandstones	0.41 to 5.48

Something of the quality and suitability of different materials for use in broken-stone pavements is shown in the following table:‡

Materials.	Co-efficients of Wear.	Co-efficients of Crushing.
Basalt	12.5 to 24.2	12.1 to 16.
Porphyry	14.1 to 22.9	8.3 to 16.3
Gneiss	10.3 to 19.0	13.4 to 14.8
Granite	7.3 to 18.0	7.7 to 15.8
Syenite	11.6 to 12.7	12.4 to 13.0
Slag	14.5 to 15.3	7.2 to 11.1
Quartzite	13.8 to 30.0	12.3 to 21.6
Quartzose sandstone	14.3 to 26.2	9.9 to 16.6
Quartz	12.9 to 17.8	12.3 to 13.2
Limestone	6.6 to 15.7	6.5 to 13.5

*Highway Construction, p. 24. †*Ibid.*, p. 26. ‡*Ibid.*, p. 172.

These "co-efficients," showing the relative quality of various road materials, were obtained by French engineers as the result of an extended series of tests, and were found to agree fairly well with the results arrived at by actual observation of the wear of materials in the roads. The co-efficient 20 is equivalent to "excellent," 10 to "sufficiently good," and 5 to "bad."

STONES NOT SUITABLE AS ROAD MATERIAL.—Before proceeding to the consideration of the stones found in North Carolina adapted to use as road material it may be well to consider briefly some of those that are not suited to this purpose. In general, it may be said that all *schistose* and *slaty* rocks, *i. e.*, all rocks which split or break easily into layers or flakes, should be discarded. No rock of whatever species which is already in the advanced stages of decay, so as to become crumbly and soft or porous, should be used in macadamizing roads, as the result in all such cases will be that, under the action of the wheels and hoofs, these materials become ground into fine powder, which becomes mud when wet, and dust when dry. There are many places, however, where a decayed granite or gneiss rock, when highly siliceous, will make a good foundation for a Macadam road, and will be found useful as a covering on clay in the improvement of dirt roads. There are other materials, like quartz ("white flint"), which are hard enough, but which are quite brittle, and hence easily crushed to powder, and which, consequently, should not be used when better material is available. Sandstones, as a rule, are unfit for use in macadamizing roads, as they are easily crushed and usually porous.

STONES SUITABLE AS ROAD MATERIAL.—"The materials used for broken-stone pavements must of necessity vary very much according to the locality. Owing to the cost of haulage, local stone must generally be used, especially if the traffic be only moderate. If, however, the traffic is

heavy, it will sometimes be found better and more economical to obtain a superior material, even at a higher cost, than the local stone; and in cases where the traffic is very great the best material that can be obtained is the most economical."* In the middle and western counties of the State, in many places, stones now covering the cultivated fields will be found satisfactory for use on the roads, and in order to get rid of them farmers will haul and sell them for low prices.

Stones ordinarily used in the construction of Macadam and Telford roads are the following: Trap, syenite, granite, gneiss, limestone, quartzite, gravel and sand. The first three of these names are used here in a very general sense, and include several species of rock which, in technical language, would be known by other names. In general, it may be said that they rank in importance about in the order named, but several of them, especially the granite, gneiss and limestone, vary so much in quality that this general statement is subject to modification accordingly.

The term *trap*, as here used, includes not only the black, rather fine-grained, igneous rock known as diabase, which occurs in long dykes in the sandstone basins of Deep and Dan Rivers, but also the somewhat similar material which is to be found in the older crystalline rock of many other regions. In this State it is often known locally under the name of "nigger-head" rock. This rock does not usually split well into paving blocks, but when properly broken it is the most uniformly good material obtainable for macadamizing public highways, though sometimes it does not "bind" well.

Syenite, sometimes called *hornblende granite*, varies somewhat in quality and composition. It is a widely distributed rock in the midland and western counties of

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*Byrne, Highway Construction, p. 170.

North Carolina, and is an excellent road material. The varieties which are finer in grain, and those having the larger proportion of the black mineral known as hornblende and are consequently of darker color, are best adapted for this purpose.

Granites vary considerably, both in quality and appearance, and in their value as road material. Those which are very coarse in grain, containing large and numerous crystals of feldspar, are, as a rule, more easily crushed and decay more rapidly, and should not be used in road construction when better materials are available. Those which contain a large proportion of mica split and crush more easily into thin flakes and grains, and for this reason are also less valuable. Those varieties which are of fine grain and contain an admixture of hornblende are best for road purposes.

Gneiss, which has the same general composition as granite, also varies very greatly in its quality and adaptability to road building. It usually has the appearance of being somewhat laminated or bedded, and when the layers are thin and the rock shows a tendency to split along these layers it should be discarded for road purposes. In addition to this, the statements made above with reference to the granites will apply also to gneiss.

Limestone suitable for road purposes is not an abundant rock in North Carolina, but it is found in a few of the eastern and a few of the western counties. It is a rock which varies very greatly in character, from the hard, fine-grained, compact magnesium limestone, which is a most excellent material for the Macadam and Telford roads, to the porous, coarse and partially compact shell-rock of recent geological formation, which is less valuable material. Practically all limestones when used as road material possess one valuable qualification, that of "binding"; the surface material which becomes ground by the action of

the wheels settles among the fragments below and consolidates the entire mass. For this reason, in many cases, it has been found to be good policy to mix a considerable quantity of limestone with some siliceous and igneous rock, which though hard and tough does not consolidate readily.

Gravel and Sand are not used in the construction of stone roads as formed by Macadam and Telford, except as an excellent foundation, for which purpose they possess a very great value; and as a binding material, in small quantities, they are sometimes spread over the road surface between the layers of crushed stone. When used in this latter connection, however, the gravel must be quite free from round pebbles. Gravel is, however, used extensively in the construction of what are termed gravel roads; where there is no attempt at macadamizing the roads, but where the gravel itself is spread uniformly over the surface of a foundation road-bed which has been properly shaped and drained. Gravel like that which occurs so abundantly in many Northern States, where glaciers existed, is not found in North Carolina. But river gravels are found in a number of our counties; and, as suggested above, in the middle and western counties there are to be found in places decayed siliceous granite and gneiss which, though not suited for mixing with crushed stone in macadamizing roads, yet will be found to serve a useful purpose as a foundation for the broken stone on clay roads, and also as a top dressing on clayey dirt roads.

DISTRIBUTION OF ROAD MATERIALS.

A line drawn from Gaston to Smithfield, Smithfield to Cary, and from Cary to Wadesboro, separates the State into two general and well-marked divisions, the eastern of which may be called the Coastal Plain region, and the western may be termed Piedmont and Mountain regions.

In the Coastal Plain Region.—In the eastern counties, except along the western border of this Coastal Plain region at irregular intervals, we find none of the hard crystalline rocks suitable for broken stone roads. Over the larger part of the area we have sand, clays and loams, the sands becoming coarser and more gravelly along the western border and finer towards the eastern. At a number of points along some of the rivers and in some intervening areas is to be found a limestone rock which will serve a fairly good purpose in road-building.

Gravel.—The gravel along this western border can be used successfully in making a fairly good road-bed, and should be used extensively where the hard crystalline rocks cannot be obtained. It may be found at many places in counties between the line mentioned above, extending from Gaston to Wadesboro, and a line drawn to the east of this from Franklin, Virginia, by way of Scotland Neck, Tarboro, LaGrange and Clinton, to Lumberton; and in a few places also considerably to the east of this latter line. The gravel is more generally distributed along the borders of the river basins, where it occurs in extensive beds, a few inches to twenty feet in thickness, though along the western edge of the Coastal Plain region it is often found on the hill-tops and divides between the rivers.

In many places the gravel is suitable for use on the road-bed just as it comes from the pit, containing pebbles of the right size, from an inch down to a coarse sand, and a small percentage of ferruginous clay, just enough to make it pack well in the road-bed without preventing proper drainage. In many cases, however, the proportion of clay and loam and sand is too large and must be reduced by the use of fine screens; and in other cases many of the pebbles are so large that they must be separated by means of a one-inch mesh screen, and those too large to pass through this screen broken before they are used.

The railroads passing through this region long since discovered the value of this gravel as a road material, and have used it extensively as a ballast on their road-beds. The small percentage of ferruginous clay soon cements the gravel into a hard, compact mass.

Limestone.—In the south-eastern portion of this region limestone rock and calcareous shells from the oyster and from fossil mollusks from the marl beds constitute the only hard materials to be found there for road construction. In some places the limestone is fairly hard and compact, as at Rocky Point, on the Northeast Cape Fear River, at Castle Hayne and elsewhere, and this rock will make an excellent road. In other places it is made up of a mass of shells firmly cemented together, as on the Trent River, near Newbern, and elsewhere. At many other points beds of shells are so slightly cemented together that the material may hardly be called a rock, as the term is ordinarily used, and in this condition it is of less value as a road material, but may be used for this purpose to advantage. A careful search will show limestone of one of these grades to occur in considerable quantities at many points in these eastern counties, between the Tar River and the South Carolina line. The harder, the more compact, and finer grained this rock, the more valuable it is as a road material; but the loose shells from marl beds, when free from clay, and the oyster-shells from the coast, when placed on a road surface and ground into fine fragments by travel, will solidify into a hard, compact road, as may be seen in the case of the excellent "shell road" between Wilmington and Wrightsville, which was built of oyster-shells.

Clay and Sand.—The admixture of a small percentage of clay or loam with the sand on the surface of the road-bed will solidify it, and will thus very greatly improve the character of the road; and in this connection, and only in this connection, clay may be considered a useful road

material. In whatever region the clay occurs in abundance the road will be greatly improved by the proper admixture of sand from an adjoining region, and by proper drainage.

Granites and other Crystalline Rocks.—These are found outcropping at intervals along the western border of the Coastal Plain region, and wherever found accessible this material should be used in the construction of roads. Near the northern border of the State they are found exposed in considerable quantity; along the Roanoke River, between Gaston and Weldon, in Northampton and Halifax counties; near Whitaker's Station, at Rocky Mount, just south of Wilson, and again a few miles north of Goldsboro on the Wilmington & Weldon Railroad. Another isolated and interesting occurrence of granite is near the junction of Pitt, Wilson and Edgecombe counties, where it is exposed over a tract of several acres. West of the Wilmington & Weldon Railroad, in the counties of Halifax, Nash and Johnston, the streams have removed the surface sands and clay in narrow strips along their borders, and have exposed at intervals the crystalline rocks; and in many places these rocks will be found to make good road material. Further south-west, in Wake county, on the Cape Fear River, and Upper Little River, in Harnett county, and again along the banks of the Pee Dee River and tributaries in Richmond and Anson counties, granitic and slaty rocks occur in considerable quantities, the former especially suitable for road material.

In considering the materials for good roads in the counties of this Coastal Plain region it must also be borne in mind that several large rivers connect this region with ample sources of granite and other good road materials which occur at the head of navigation on these streams and can be cheaply transported on flats; and further, that a number of railroads pass from the midland counties

where the supply is abundant directly into and across the Coastal Plain region.

Plank Roads.—As suggested above, in deep sandy regions where timber is abundant the plank road may prove the most economical good road that can be built for temporary use, and some of them last six to ten years. But the greatest objection to them lies in the fact that when the timbers decay, whether this be at the end of four or ten years, the road is gone; and the entire cost in labor and money must be repeated.

IN THE MIDLAND AND PIEDMONT COUNTIES.—Throughout the midland and Piedmont counties of the State, west of the Coastal Plain region, rocks suitable for road purposes are abundant and widely distributed, so that no one can claim as an excuse for *bad* roads that the materials are not at hand for *good* roads. It will serve our present purpose to discuss these in the order of their geographic distribution, with but little regard to their geologic relations.

Trap Rock in the Sandstone Areas.—As stated above, sandstones possess very little value as road material, especially when broken into fragments, as is necessary in making Macadam and Telford roads, but fortunately in this respect the sandstones of North Carolina are quite limited in their distribution. The larger of the two areas begins near Oxford, in Granville county, and extends south-westward, passing into South Carolina below Wadesboro. It has its maximum width of about sixteen miles between Chapel Hill and Cary, and its average width is less than ten miles. It occupies the southern portion of Granville county, the southern half of Durham, the western border of Wake, the south-eastern border of Chatham, and portions of Moore, Montgomery, Anson and Richmond counties. The other sandstone area is much more limited in extent. It lies mainly in Stokes and Rockingham counties, along the Dan River, between Germantown and the Virginia line, a

length of not more than thirty miles, and a maximum width of not more than five miles.

Fortunately for the roads leading through these sandstone areas there is an abundance of a hard, black, tough, fine-grained rock, known as diabase, or trap, occurring in dykes which have broken through the sandstone and now appear on the surface in lines of more or less rounded black masses of rock running nearly north and south. These dykes vary in width from a few feet to more than one hundred feet, and are separated from one another by distances varying from a few yards to two or three miles. A dozen or more of these dykes are crossed by the wagon road between Chapel Hill and Morrisville. Several dykes occur at and near Durham, and the rock has been used upon roads leading out from Durham, but unfortunately it has not been crushed into small fragments, as should have been done, and hence the result has not been altogether satisfactory.

There is, probably, in both these sandstone areas a sufficient amount of trap rock to properly macadamize every prominent road that crosses them, and, after this has been done, to furnish a top dressing for all public roads which are likely to be macadamized in the adjacent counties.

Trap Rock in Other Areas.—Fortunately this excellent road material is, in its occurrence, not limited to the sandstone regions. Dykes quite similar to those which abound in the areas just described are also found extending across the country in many of the midland and Piedmont counties, and also the region west of the Blue Ridge. Heretofore this black, "nigger-head" rock, as it is frequently called, has been regarded as a useless encumbrance of the ground; now, in connection with the move for better roads, it must be regarded as one of our most valuable rocks. The city of Winston has already made extensive use of it in macadamizing its streets, with excellent results.

The Eastern Granite Belts.—Granitic rocks are abundant over considerable areas in the midland and Piedmont counties, and especially in the former. One of these important areas may be called, as a matter of convenience, the Raleigh granite belt; which, in a general way, may be described as enclosed by lines drawn from Gaston to Smithfield, thence to a point midway between Raleigh and Cary, and thence a little east of north to the Virginia line. This belt occupies a considerable part of Wake, including the region about Raleigh, of Franklin, and practically the whole of Warren and Vance counties. The principal rocks of this belt are light-colored gray, comparatively fine-grained, granite and gneiss; on the whole a fairly good material for road construction. The rocks vary in composition and in appearance at different localities, but are fairly uniform in character over considerable areas. In some places the black or biotite mica is largely wanting, and the rock assumes a whitish feldspathic character; at other points the mica becomes abundant, and the rock assumes a dark gray color. In places the mica is so abundant that the gneiss becomes somewhat schistose, or laminated, and in this condition crushes easily, hence should not be used on the roads. Dykes of trap rock are occasionally met with, and these should be used in preference to the gneiss and granite wherever accessible.

The somewhat isolated patches of granite lying east of this belt in Halifax, Nash, Edgecombe and Wilson counties have already been referred to.

West of the Raleigh belt there is another granite area of limited extent which occupies the extreme north-eastern portion of Durham county and the larger part of Granville county. This may be called the Oxford granite belt. The rocks of this area resemble to some extent those of the Raleigh belt, but there is a larger proportion of syenitic and trap rocks, which make excellent road material.

The Central Granite Belt.—This belt extends obliquely across the State from near Roxboro, in Person county, to the South Carolina line along the southern border of Mecklenburg. Its width varies from ten to thirty miles, and it occupies a total area of about three thousand square miles in the following counties: Western half of Person, including the region about Roxboro; the south-eastern portion of Caswell, the north-western half of Alamance, the larger part of Guilford and Davidson, south-eastern portions of Davie and Iredell, Lincoln and Gaston and the larger part of Rowan, Cabarrus and Mecklenburg. In this belt throughout its entire extent road material of most excellent quality is abundant. The prevailing characteristic rocks are syenite, dolerite (trap), greenstone, amphibolite, granite and porphyry; and, as will be seen from this list, the tough hornblende and augite rocks predominate. Dykes of trap rock, some of them of considerable extent, are to be found in almost every portion of the belt. So uniformly tough and durable are these materials that one could hardly go amiss in making selections for road construction.

The Central Slate Belt.—This region lies just east of the central granite belt, and extends obliquely across the State from Virginia to South Carolina. Its eastern border lies against the Deep River sandstone basin described above (p. 23). It varies from twenty to forty miles in width and includes all or portions of the following counties: The eastern half of Person, the north-western part of Durham, the south-eastern part of Alamance, nearly all of Orange, Chatham, Randolph, Montgomery, Stanly and Union; the eastern part of Davidson and Rowan, and the north-western part of Anson. A considerable portion of this area is rich in other mineral products, but the entire belt, as compared with the central granite belt, is poor in road materials. The rocks are mostly siliceous and clay slates, with a considerable admixture of chloritic and hydromicaceous

schists; all of which are at best inferior for road construction. Here and there, however, trap dykes are found in this belt; and in places the siliceous slates become somewhat massive, passing into hornstone and a quartzite, which, when crushed, will answer fairly well for macadamizing purposes. In other places the chloritic schists become somewhat massive and tough and can be used in the same way. In still other places, as about the State University, and along the eastern border of Orange county, the rock is a fine-grained, tough syenite, accompanied by trap dykes, and is eminently suited for road purposes; and again, as near Hillsboro, granite occurs in a limited area. Vein quartz ("white flint") is abundant in many parts of the belt; and, though not usually recommended as road material, is worthy of consideration. While, then, on the whole the rocks of this belt are not suitable for use as road material, yet a careful search will show the existence of a sufficient quantity of material of fair quality to macadamize all the public roads. And should this supply ever prove insufficient, excellent materials are to be found in abundance in the granite belt along the western border of this region, and in the trap dykes of the sandstone on the eastern border.

The Gneisses and Other Rocks of the Piedmont Counties.—West of the central granite belt as described above, and extending back to the foot-hills of the Blue Ridge, is the region occupied by the Piedmont counties—Rockingham, Stokes, Forsyth, Yadkin, Surry, Wilkes, Davie, Iredell, Alexander, Caldwell, Burke, McDowell, Rutherford, Polk, Cleveland, Catawba, Lincoln and Gaston. The rocks of this region resemble in many respects those of the Raleigh granite belt. They consist of a succession of gneisses, schists and slates, more hornblendic toward the east and more micaceous toward the west, with here and there masses and dykes of syenite, trap and other eruptive rocks.

In places, as at Mount Airy, the true granite occurs in considerable abundance. The granites and gneisses, except where the latter tend to split into thin layers and crush, are fairly good materials for road construction, improving as they become finer in grain and as the percentage of hornblende increases; but the best material for road construction is to be found in the trap dykes and syenite ledges which at intervals traverse this region, more especially its eastern half.

The Gneisses and Other Rocks of the Mountain Counties.—The rocks of this region are not greatly unlike those of the Piedmont counties just described. Over much the larger part of the area rock fairly well adapted to road construction is abundant, indeed so abundant that the laborers on the public roads in that region during the past half century have expended the larger part of their time and energy in endeavoring to get this rock out of the way. Had they expended this time and energy in crushing the rock and spreading it over a well-formed foundation, this region would possess at the present time a number of excellent macadamized highways.

In the more northern counties—Alleghany, Ashe and Watauga—the predominating rocks are hornblende gneiss and slate, but massive syenites are abundant, especially between Rich mountain in Watauga and Negro mountain in Ashe county, and elsewhere. Further south-west, through Mitchell, Yancey, Madison and Buncombe counties, hornblende schists still continue, but they are more massive, and the gneisses predominate. These are, on the whole, compact and sufficiently tough for use in the construction of good Macadam roads. And the statement just made concerning these counties is also applicable to Henderson, Transylvania and Haywood counties, and in a measure to Jackson, Swain and Macon counties and the eastern half of Clay county, in all of which the supply of good road

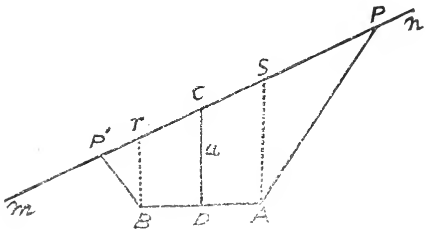
material is ample; but in these last three counties mica schist partially replaces the hornblende slate. In the western part of Swain, in Graham, Cherokee and the western part of Clay county good road material is not so abundant as in the other counties named, but nevertheless is to be found in considerable quantities. The rocks over a considerable portion of this last-named area are micaceous and hydromicaceous in character, and are practically worthless for the purposes of road-building, but the quartzite ledges and beds of limestone in these counties will furnish ample and suitable material.

In conclusion, it may be said that in the middle and western counties of North Carolina material suitable for macadamizing the public highways is abundant and generally accessible. It will be the exception, rather than the rule, that this material will have to be transported for any considerable distance. In the eastern counties materials suitable for this purpose are inferior in quality and only moderately abundant in quantity, but the extensive and intelligent use of even these materials would very greatly improve the public roads and thereby increase the prosperity of the people. And in many places where the Macadam road is at present out of the question on account of the lack of stone, other materials, gravel, clay, loam and plank will be found in sufficient abundance to make the construction of better roads practicable at reasonable cost.

TO SET SLOPE STAKES WHEN THE SURFACE IS STEEP BUT SLOPES UNIFORMLY.

BY J. M. BANDY.

Let mn represent the surface of the ground. Let C represent the position of the centre peg, and let CD ($=a$, the value of which is found from the level notes) represent the centre cut. The width of the road, BA, is b.



It is proposed to find what engineers designate as cuts at P, P^1, S, and T.

In the direction of P, and in connection with C, one setting of the rod determines the slope of the ground mn. Call this slope m. Now, since the cds. of C are (o, a), the equation of the surface, mn, is

$$y = mx + a, \quad \ldots \ldots \quad (1).$$

The quality of the soil determines the slopes of PA P^1B. Call this slope m^1. Then since the cds. of A are $(\frac{b}{2}, 0)$, the equation of PA is

$$y = m^1x - \frac{m^1b}{2}, \quad \ldots \ldots \quad (2).$$

Combining (1) and (2), the cds. of P are known. Hence the cut at this point is known.

Designating the cds. of P, just found, by (x^{11}, y^{11}) and the cds. of C by (x^1, y^1) $[=(o, a)]$,

$$CP = \sqrt{(x^{11} - x^1)^2 + (y^{11} - y^1)^2}, \quad \ldots \ldots \quad (3).$$

Then measure this distance, CP, and fix stake at P.

The equation of SA is

$$x = \frac{b}{2}.$$

Substituting this value in (1), the cut S is at once obtained. Denoting the cds. of S by (x^{11}, y^{11}) and the cds. of C by (x^1, y^1), and substituting in (3), CS is known. Measure this distance, and fix stake at S.

The same course of reasoning applies in finding the cuts at P^1 and T.

The writer has found this method more expeditious than *trial* and *error* when the surface was much inclined. The numerical computations did not require as much labor as manœuvering with the rod and level.

Since he has not seen the above method in any of the books which have fallen under his eyes, he has been induced to give it in the hope that it might prove useful, as well as suggestive, to others under similar circumstances.

TRINITY COLLEGE, N. C.

ON THE DEVELOPMENT AND A SUPPOSED NEW METHOD OF REPRODUCTION IN THE SUN-ANIMALCULE, ACTINOSPHÆRIUM EICHHORNII.*

BY JOHN M. STEDMAN.

Early in March my attention was called to an aquarium which had been standing in my window during the winter, and which contained anacharas and algæ in great abundance, but which now suddenly presented a quantity of light pink substance on the sides of the jar. It was the appearance of this pink-colored material among the *debris* of decaying and growing algæ that attracted my attention. Accord-

*Amer. Soc. Microscopists, 1888.

ingly a small piece of the substance was spread out on a slide and examined, when, to my surprise, it was found to be composed of sun-animalculæ of various sizes, among which were other bodies, the true nature of which I did not at first quite understand, but which on close examination proved to be the young of the larger heliazoa. So numerous, indeed, were the young heliazoa that not a single field of the one-fifth objective and *a* ocular could be chosen in which there were less than half a dozen, and usually the number was very much greater.

Such an unusually great and rare opportunity to study these animals could not be neglected. Fortunately they were discovered in the morning, and by close and constant observation for several hours their true relations to the numerous small bodies were satisfactorily demonstrated and proven to be different stages of the same animal.

For a description of *A. Eichornii* and of its habits see "Fresh-water Rhizopods of North America," by J. Leidy, p. 259. Plate XLI.

We will pass at once to the special subject in hand, beginning, for convenience, with the simplest or youngest heliazoan.

Development.—Let it not be understood that the order in which I am now to describe the different stages of development is the order in which I observed them. On the contrary, what I shall first describe really came about last in my observations, since I did not at first take the youngest stages of this heliazoan to have any connection with the larger heliazoa. My observations began with an undoubted heliazoan of this species (Fig 13 of my plate), and from that I worked both ways, but principally to the younger. It would have been impracticable to have watched the development of a single heliazoan from the very youngest individual to the full-grown animal, since it would have required not only a constant observation for a

much longer time than I could spare, but would also have needed some little care. As it was, I could watch a young heliazoan until it had developed a few stages, and had considerably lessened the near supply of food, and then I could find another heliazoan of the same stage as the one just discarded, but which was in more favorable circumstances for further growth. As indicated, the number of heliazoa was enormous, and the different stages were represented by the score. Had I suspected these various stages to have been what they were, there would have been no trouble in finding a complete set, for every gradation from the youngest to the adult was present in great quantities. Fortunately there were quite a number of worms—*Dorylaimus stagnalis*—in the water, and their constant wriggling about kept the heliazoa and other animals in perpetual motion, so that they came in contact with one another, where otherwise they would not have done so.

A far greater number of observations were made than I shall here describe. Enough were chosen, however, to form a complete series, and accurate drawings made of them. I shall, therefore, describe only those observations which I have illustrated, hoping that the series will be full enough for our purpose.

I think it is safe to say that were this minute mass of protoplasm which constitutes the youngest heliazoan observed by itself for a little while, no one would mistrust its true nature or relations. Indeed it was only after a long and continued observation, and that under the most favorable circumstances, that I became convinced of its true nature. It is nothing but a minute spherical mass of finely granular and hyaline protoplasm, 14.5 μ in diameter, with a contained nucleus and a distinct nucleolus (Fig. 1). In appearance it resembles white blood corpuscles with a distinct and sharply defined nucleus. Later, however, a vacuole appears in its substance, and, increasing in size,

often becomes larger than the original mass of protoplasm, so that the latter forms but a thin layer surrounding it (Figs. 2, 16, 12). In this stage a pseudopodeum or ray may be presented (Fig. 12).

Two heliazoa of the first stage were seen to come together, which, however, as in nearly all cases, was due to the agitation of the water by the worms, and immediately upon touching one another (Fig. 23), to fuse and run together just as a drop of water fuses with another drop of water. It is impossible to say which of the two was devoured; both appeared to play an equal part, the vacuole and nucleus of both being present, and the whole immediately assuming a spherical form and appearing (Fig 3) much like any one of the two of which it is now composed, except that it has two vacuoles and two nuclei. In the course of five minutes this young, two-vacuoled, heliazoan had developed a ray, and in its interior the characteristic axis thread could be distinctly seen (Fig. 20). The absence or the number of rays when present in the young heliazoa is of no special value, and varies with different individuals of the same age, as will be seen from the figures.

Whether this fusion of two individuals of the same species be called eating or not does not concern us, and I shall not attempt to discuss the subject here. As a matter of fact, however, it is not conjugation for purposes of reproduction or rejuvenescence, as will be seen later; and, since we have these animals developing by this method of increase as well as by that of an undoubted eating of other animals, it matters not, so far as development is concerned, whether they appropriate material so near like that of their own bodies that it needs no change to form a part of them, or whether the food be different and hence have to be changed or digested before it can be so appropriated. I have observed farther advanced heliazoa capture infusoria and amoeba and surround them, and draw them into their

interior, where they remained to be digested; and at the same time I have observed those same heliazoa capture other heliazoa, and instead of drawing them into their interior and surrounding them as they did other bodies, they would draw them in until the two heliazoa touched, when there occurred a fusing and blending of the two animals into one just so much larger. My only explanation is that, as indicated, the protoplasm of the two animals is *exactly alike* and hence there can be no need of digestion. Were one of the heliazoa dead when it came in contact with another which would otherwise have fused with it, I have no doubt but that the dead heliazoan would be surrounded and drawn into the interior of the live one the same as other animals are and there digested, it being *not exactly like* the protoplasm of the one which is alive. For if this were not the case, if the dead heliazoan upon contact with the living heliazoan were to form a part of it as the living heliazoan did, then we should have a case where simple contact of the living protoplasm with the same but dead protoplasm would impart life to the dead, just as a piece of iron which is magnetized, if brought in contact with one which is not, will impart magnetism to it. But it is needless to say that such a phenomenon of life has never been observed.

While watching the heliazoan (Fig. 3, 20) which we have just described as being the result of the union of two of the youngest individuals (Fig. 2, 23), the water was stirred by a worm, and another heliazoan, of about the same size as the one under observation; but with three vacuoles and no rays, was brought nearer and nearer until finally they accidentally came in contact with one another and immediately united (Fig. 20) and assumed a spherical form. Presently the single ray disappeared and three more vacuoles made their appearance in the mass of protoplasm together with the development of a contractile vesicle

(Fig. 5). This individual was watched until it had developed three rays and several more vacuoles (Fig. 6), a process requiring about twenty-five minutes, during which time it had eaten nothing except one of the youngest heliazoa without a vacuole. Under the one-twelfth oil emersion I was able to detect the axis cylinder in two of the rays, but not without some doubt in the third ray.

Very near this individual (Fig. 6, 26) was another heliazoan of a much greater size (Fig. 25), and by touching the cover-glass with a needle I soon brought the two so near that the tip of one of the rays of the smaller heliazoan touched the larger animal. Wishing to observe the result of this contact I waited a few minutes, when it became apparent that the smaller individual was drawing in its ray, which was in contact with the larger heliazon, and was thus drawing itself towards it. The larger animal, offering the greater resistance, did not appear to move. Five minutes from the time the ray first touched the other heliazoan the two had come in contact, whereupon a union occurred and immediately the two blended into one. The smaller animal appeared to flow into the larger and to disperse itself through it in a manner which is common to all these animals, young as well as full-grown, and which will be described later when we reach a nearly mature heliazoan. Before the union of these two animals they appeared alike except in size and number of vacuoles, but shortly after the union the granules in the protoplasm gradually moved towards the center of the animal, where they became more numerous, and instead of being evenly distributed throughout the granular protóplasm now formed a central, more granular portion with an outer, clearer, and less granular zone. Three more rays were also developed, and the animal presented the appearance shown in figure 7, which, at this stage, would probably not be mistaken for any other species. Hundreds of individuals

were to be found of this size and appearance, and hence it was not necessary to watch the development of this single individual longer, as other fields promised better results.

There was almost an unlimited supply of heliazoa intermediate in size between the two whose union produced the one just mentioned. They differed in no respect from one another or from the two just mentioned, except a slight difference in size, and every gradation between them was to be found. Merely for the sake of filling up the gap which exists in regard to size between the two individuals whose union we just referred to, I will cite one example out of many which I have observed. Two similar individuals, slightly larger than the smaller (Fig. 26) of the two just united were seen to come together (Fig. 22), and, as a result of their union, a heliazoan was produced so nearly like the larger (Fig. 25) of the two of the former individuals, that there was practically no difference between them.

Another field was now chosen in which were a number of heliazoa, similar in all respects to the one representing our last stage (Fig. 7). I had not waited long before it was evident that two of these animals were gradually approaching one another from some cause which I was unable to discover. When within a very short distance, in fact, almost ready to meet, there occurred a very singular movement on the part of both individuals—a movement which I can hardly account for—in which there was produced a swelling, as it were, in that part of the sphere of both animals (Fig. 8, 9) which was just about to touch the other, and by continued enlarging with increased rapidity soon met one another, thus uniting the two individuals much more quickly than they otherwise would have done. Immediately upon touching one another the at first narrow neck uniting them rapidly enlarged (Fig. 10), the protoplasm of the one flowing into the other and *vice versa* until

the two animals had united into an oblong-shaped mass. The flowing of the protoplasm from one to the other was a most interesting sight, and could be distinctly seen, owing to the numerous granules which it contained. Both animals played an equal part in the union; a current of protoplasm could be seen streaming from the first into the second, and near it another current from the second into the first. There were as many currents as there were threads of denser protoplasm uniting them. Like all the observed cases the denser and more granular portions of the protoplasm separating the vacuoles from one another never mixed with anything but the corresponding protoplasm of the individual with which it united; hence there was no destruction of vacuoles, but merely an addition or union, and, moreover, the peripheral layer of vacuoles always remained on the periphery, while the central mass of vacuoles flowed to the center of the united mass. The heliazoan now gradually changed from the oblong or ellipsoid shape to that of a sphere (Fig. 11), and here I left it to seek other fields.

A nearly identical individual to the one just mentioned was found and seen to capture by one of its rays another but smaller heliazoan. As a result of a movement of the water the smaller individual chanced to come in contact with the tip of a ray of the larger animal and there to unite with it, whereupon the larger heliazoan gradually drew in its ray and the smaller creature with it. It was an interesting sight to see this process. The ray seemed rather to flow into the spherical mass or body of the animal, since a stream of protoplasm was rapidly and constantly flowing down its center into the animal, and the smaller heliazoan was likewise flowing into the larger by this means; but, nevertheless, the ray grew shorter and shorter until finally the heliazoa came in contact (Fig. 13), and then a union took place similar to the one described above,

except that here the flow of protoplasm appeared to be solely from the smaller to the larger animal. Before the animal had become entirely spherical, the denser inner portions of the smaller heliazoan had united with that of the larger and appeared as a swelling upon it, while the peripheral zones of both animals had united. This appeared to be such a good example of the mode of union of the protoplasm of two heliazoa that I figure it (Fig. 15).

I have observed a number of large heliazoa capture the youngest individuals, and in all cases as soon as the young animal touched the ray of the larger it appeared, so to speak, to form a part of it, and would sometimes assume an oval form and remain on the ray, looking exactly like the little knobs of protoplasm which are frequently seen there, except that it would be larger; and then again I have seen them flow down the center of the ray, while the ray itself suffered no appreciable change. In one instance, however, which came under my observation, a moderate sized heliazoan (Fig. 17) captured by the tip of its ray one of the youngest individuals (Fig. 16), and while watching to see what would happen to this young one, the ray of a large heliazoan (Fig. 18) came in contact with the larger of the former animals. Out of curiosity merely I watched to see the result of this extraordinary union, and found that the largest heliazoan drew its captured brother to itself and united with it before the smallest individual had touched the body of the one to which it was attached; the smallest heliazoan then appeared to be fastened to a ray of the largest animal, which, however, soon drew it to itself and the two united.

Quite a different process from the one we have been discussing occurs when the heliazoan encounters food consisting of other animals or plants. I have no doubt but that the youngest heliazoan, as well as those of all stages, are able to and generally do develope and reach maturity by

the use of no food other than that of other animals and plants; but there is also no doubt that this is a process requiring considerable time as compared with that which occurs when they chance to meet with their own kind, since in the former case the food has to be digested, while in the latter it has not. It was my good fortune to find a large heliazoan which had just captured an infusorium and partially surrounded it. In a few minutes the infusorium was completely enclosed, a clear space remaining around it, however, and gradually it was moved near the center of the animal, where it could be seen slowly moving its cilia in the little water which immediately surrounded it and which separated it from the protoplasm of the heliazoan (Fig. 19, 21). Presently an amoeba came in contact with the heliazoan and appeared to stick to it more or less and to constantly try to move away from it. The heliazoan made several efforts to surround it, but the amoeba in every case moved out before being fairly imbedded, and finally, after several minutes of hard struggling to ascertain which was to be victorious, the amoeba escaped. It was but a short time, however, before another amoeba chanced to touch the heliazoan, and this time with better success to the heliazoan. The amoeba, as soon as it touched the heliazoan, spread out a little on it, and at the same time the protoplasm of the heliazoan began to flow around and to enclose the amoeba, which now made several efforts to escape, but in vain, for within a few minutes a fine film of protoplasm had surrounded it, and the amoeba was within the heliazoan (Fig 19). A quantity of water was also enclosed with the amoeba, and in this it exhibited considerable activity, even after it had been carried nearly to the center of the heliazoan (Fig. 21). It was not long, however, before the amoeba had assumed a globular form and become motionless. I mention this instance in which the heliazoa eat other animals merely to bring out the strik-

ing difference between the process and that observed when they eat their own species.

Dr. Joseph Leidy* speaks of having found several globules of granular protoplasm with vacuoles and rays, and alludes to their probable connection with this species of heliazoa. I have reproduced in figure 24 one of his figures of these bodies, and think that there is every reason to believe that they are what he suspected them to be.

Reproduction.—It is not uncommon to find heliazoa in the process of reproduction by fission; in fact, if heliazoa be kept for any considerable length of time they are almost certain to be found in the act of reproducing by this means. I have observed them divide by keeping them in a watch-glass under the microscope, and in one instance I watched uninterruptedly the process, from an oral heliazoan before the constriction began to appear, up to the division and entire separation into two animals. A complete set of drawings was made to illustrate the different steps, and I find by referring to my notes that one of the drawings is almost identical with figure 10, which represents the heliazoan in the process of union.

As regards reproduction in the heliazoa outside of the well-known process of fission, all I can say is from a philosophical stand-point, as no direct observations have been made outside that of the finding of the young. But the presence of young has got to be explained in some way. From Dr. Leidy's "Fresh-water Rhizopods," p. 260, I find that "according to Stein, Carter and other authorities, *A. Eichhornii* contains many nuclei, large individuals having a hundred or more." Whether this has any connection with the heliazoan's having devoured individuals of its own species and thus to have retained their nuclei, and so, by continually adding to the number every time it captured

*"Fresh-water Rhizopods of North America," page 262-3.

another heliazoan, to have finally attained the number of one hundred, or whether it is connected with the process of reproduction, I cannot say. It seems to me very probable that, in the fall at least, the full-grown heliazoan becomes encysted, and that its protoplasm then divides and subdivides, until it is converted into a mass of minute bodies, which, when the cyst is ruptured, make their escape into the surrounding water, and then appear as naked, spherical masses of granular protoplasm with a nucleus. It may be that the minute bodies acquire a covering before they escape from the mother cyst, and that they then act as spores, and are carried about and developed similar to the spores of infusoria.

Of course this mode of development has never been observed in the heliazoan, but it seems to me to be very probable that it does occur, judging from the observed young individuals, and from the fact that it occurs in certain infusoria.

EXPLANATION OF PLATE.

All the figures were drawn from life except Fig. 24, which is a reproduction of a figure from Dr. Leidy's work on the Rhizopods. Fig. 1, which is a heliazoan, *Actinosphaerium Eichhornii*, of the very youngest stage, is in nature 14.5 *u* in diameter. The other figures are drawn with the same magnification as Fig. 1, and hence they all bear the same relative size in nature as is here represented, excepting Figs. 25 and 26, which are a little too small. I take it to be of much more value to the reader to have the figures drawn so as to preserve their relative size, and then to know the natural size of one of them, than it is to have the figures of various magnifications and know the magnification of each separate figure. I do not wish it understood that the figure taken from Leidy is relatively of the same size as the other figures.

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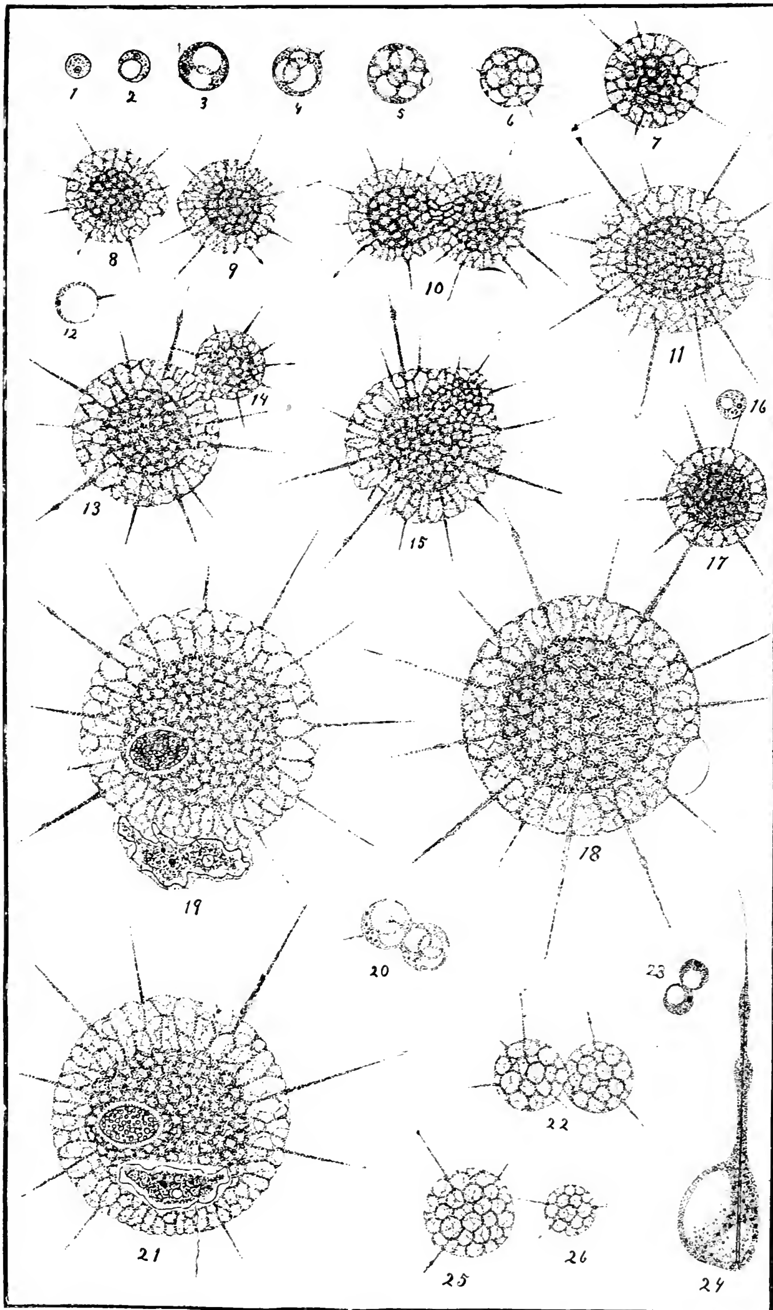

J. M. Stedman. Del.

SOME FUNGI OF BLOWING ROCK, N. C.

BY GEORGE F. ATKINSON AND HERMANN SCHRENK.

During the month of August for the summers of 1888 and 1889 it was the good fortune of the senior author of this paper to spend that time in the enjoyment of the invigorating atmosphere and famous scenic beauty of this point in the Western North Carolina mountains.

To the greater number of the readers of this Journal Blowing Rock is not unknown. It may be a matter of interest to others to know that this now fast becoming popular summer resort is found in Watauga county, and is reached by "staging it" twenty miles up the mountain from a point, Lenoir, the northern terminus of the Chester & Lenoir Narrow Gauge Railroad, which connects with the main line of travel from the east and west at Hickory, on the Western North Carolina Railroad.*

Even a botanist can cherish commendable curiosity, on his first trip to the place, concerning its "*entitlements.*" Upon reaching the summit near the village one is sped through an unpretentious drive of nearly one mile when the road curves to evade a steep hill. Here is suddenly presented to view the grand panorama of the great John's River valley below and the lofty peaks of the Black Mountains beyond.

When one has become disengaged from travelling paraphernalia, and when rest and refreshments have dispelled fatigue, there comes an irresistible desire to join others in the pilgrimage to the "Rock." Once there the meaning of "Blowing Rock" becomes apparent. The rock juts out upon the west side of the cliff, forming a bold precipice at the north-east of the John's River valley. The currents of

air from the farther end of the valley converge as they rise at this point, favored by the cliffs at the north and east, and on an otherwise calm day quite a strong breeze "blows" over the rock. Throw your hat, walking-stick, or whatnot over the precipice and the wind brings them back to you. Legend has it that a despairing lover once leaped from the side of the fair one over the rock and the cruel winds picked him up and brought him back to her feet! It is proper to say, however, that when the writer visited the spot the winds did not seem to be "getting in their work" properly and there was no inclination to jump.

But legends and levity both aside, Blowing Rock is prodigal with flowers and "mushrooms." To one who visits the place in June the profusion of thickets painted with *Rhododendrons* and *Kalmias* are a "joy forever." Later in the season "Black-eyed Susans" wink at you here and there, and various species of interesting *Orchids* are frequently met with. *Eupatoriums* and other vigorous growers vie with each other in their effort to hide the fences which line the roads or cross the fields.

The great prodigality of the fleshy fungi tempted the writer, during portions of two short months, to form the beginning of a closer acquaintance with the *Hymenomycetes* than had been gained from a general study of structure and relationships. Accordingly collections were made of fungi chiefly in this group. Not wishing to be encumbered with books, no efforts were made at the time to identify the specimens. A few notes were taken on the more evanescent characters, the specimens were then dried and preserved for future determination.

The greater number of the *Hymenomycetes* were afterward determined by Mr. A. P. Morgan. Dried agarics are very difficult of determination and it is a matter of some interest that more than half of the *Agaricaceæ* were in a recognizable condition, though some genera like *Cortinarius* were complete failures.

One point of interest in making the collections was the observation that quite circumscribed areas for several days in succession would yield fresh and abundant specimens of the same species. Near Fair View and Sunset Rock *Boletus americanus* was abundant both seasons. A trip down the damp slopes of Glen Burney was almost sure to be rewarded by gorgeous *Thelephoras.* Partly down the John's River valley road, in rather open woods, several species of *Hydnum* would always insist on over loading one's basket. That lovely plant, *Mitremyces lutescens* Schwein., cropped out continually along certain of the shady clay road banks dripping with water. From the same situations where there was less water, clammy *Amanitas* lifted their heads. One point on the Valley Crucis road yielded *Strobilomyces strobilaceus.* Wonder Land produced monster clusters of *Clitocybe illudens.* At one time I could have picked more than a bushel without moving from the spot. This plant is remarkably phosphorescent, the phosphorescence being confined to the hymenium. Sometimes this plant is taken to the hotels, and at night the guests amuse themselves delineating various figures in the dark with the aid of this "fox-fire" mushroom. Another phosphorescent plant, *Panus stipticus*, is common upon dead stumps, etc. Close by the roadside at Wonder Land, also, *Cyclomyces greenii* was found. In an open field east of the Morris pasture the parasol, *Lepiota procera*, grew in abundance, and here and there the Ox-tongue, or beef-steak fungus, *Fistulina hepatica*, offered its juicy meat. *Lactarii* were everywhere and so the dainty *Marasmii.* *Marasmius capillaris* was taken, just a bit of it, from "Flat Top." *Bulgaria inquinans*, *Spathularia velutipes*, *Leotias*, were very common. The *Geoglossums* were rarely seen. *Geoglossum Walteri* was collected by Miss Etta Schaffner down in the John's River valley near the foot of Fair View. Down in the far depths of this valley was a profusion of the maiden's hair fern, *Adiantum capillis-veneris.*

The junior author, Mr. Schrenk, a student in botany in my laboratory, has rendered valuable service in making out the list presented below and in a careful examination of the specimens for the purpose of verification of the identifications, in order to lessen the chances of error. This has occasioned no inconsiderable labor on his part.

In the arrangement of the list the system presented in Saccardo's Sylloge has been mainly followed. No effort has been made at changes in nomenclature, since it did not seem to be called for in a bare list of no more than 254 species.

The *Saccharomyces pyriformis* and *Bacterium vermiforme** were symbiotic organisms composing small amber-colored grains termed "moss seed," "California beer seed," used by some of the mountain people in brewing a beer by placing the grains in water sweetened by molasses. The grains were given me by Dr. Carter, a resident physician.

ORDER HYMENOMYCETEÆ.

FAMILY AGARICACEÆ.

1. *Amanita cæsarea* Scop.
2. *A. muscaria* Linn.
3. *A. pantherina* DC.
4. *A. phalloides* Fr.
5. *A. recutita* Fr.
6. *A. solitaria* Bull.
7. *A. vernus* Fr.
8. *Amanitopsis vaginata* (Bull.) Roz.
9. *A. volvata* (Pk.) Sacc.

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*See Ward. The "Ginger-beer plant," and the organisms composing it: a contribution to the study of fermentations—yeasts and bacteria. Proceedings of the Royal Society, Vol. 50, pp. 261, 265.

10. *Lepiota cristata* Alb. et Schwein.
11. *L. procera* Scop.
12. *Armillaria mellea* Vahl.
13. *Tricholoma fulvellum* Fr.
14. *T. portentosum* Fr.
15. *T. saponaceum* Fr.
16. *Clytocybe cyathiformis* Fr.
17. *C. illudens* Schwein.
18. *C. infundibuliformis* Schæff.
19. *C. laccata* Scop.
20. *Collybia confluens* Pers.
21. *C. radicata* Relh.
22. *Mycena corticola* Schum.
23. *M. galericulata* Scop.
24. *M. mucor* Batsch.
25. *M. stipularis* Fr.
26. *Omphalia fibula* Bull.
27. *O. scabriuscula* Pk.
28. *Pleurotus applicatus* Batsch.
29. *Hygrophorus cantherellus* Schwein.
30. *Lactarius albidus* Pk.
31. *L. chrysorrheus* Fr.
32. *L. cilicioides* Fr.
33. *L. cinereus* Pk.
34. *L. corrugis* Pk.
35. *L. fuliginosus* Fr.
36. *L. helvus* Fr.
37. *L. hysginus* Fr.
38. *L. insulsus* Fr.
39. *L. lignyotus* Fr.
40. *L. pergamenus* (Swartz) Fr.
41. *L. piperatus* (Scop.) Fr.
42. *L. pyrogallus* (Bull.) Fr.
43. *L. rufescens* Morg.
44. *L. rufus* (Scop.) Fr.
45. *L. subdulcis* (Bull.) Fr.

46. *L. subtomentosus* B. et Rav.
47. *L. subpurpureus* Pk.
48. *L. theiogalus* (Bull.) Fr.
49. *L. torminosus* (Schæff.) Fr.
50. *L. volemus* Fr.
51. *Russula furcata* (Pers.) Fr.
52. *Cantherellus aurantiacus* Fr.
53. *C. cibarius* Fr.
54. *C. cinereus* Fr.
55. *C. floccosus* Schwein.
56. *C. infundibuliformis* (Scop.) Fr.
57. *C. minor* Pk.
58. *C. princeps* B. et C.
59. *C. wrightii* B. et C.
60. *Marasmius anomalus* Pk.
61. *M. archyropus* (Pers.) Fr.
62. *M. capillaris* Morg.
63. *M. ferrugineus* Berk.
64. *M. melanopus* Morg.
65. *M. plectophyllus* Mont.
66. *M. præacutus* Ellis.
67. *M. rotalis* B. et Br.
68. *M. salignus* Pk.
69. *M. viticola* B. et C.
70. *Lentinus lecomtei* Fr.
71. *L. lepideus* Fr.
72. *L. strigosus* Fr.
73. *Panus stipticus* (Bull.) Fr.
74. *Lenzites betulina* (Linn.) Fr.
75. *L. cookei* Berk.
76. *L. cratægi* Berk.
77. *Pholiota squarrosoides* Pk.
78. *Crepidotus fulvo-tomentosus* Pk.
79. *Paxillus flavidus* Berk.
80. *Agaricus campester* Linn.

FAMILY POLYPORACEÆ.

81. *Boletus americanus* Pk.
82. *B. auriporus* Pk.
83. *B. badius* Fr.
84. *B. castaneus* Bull.
85. *B. chrysenteron* Fr.
86. *B. collinitus* Fr.
87. *B. felleus* Bull.
88. *B. flavidus* Fr.
89. *B. gracilis* Pk.
90. *B. granulatus* Linn.
91. *B. leprosus* Pk.
92. *B. purpureus* Fr.
93. *B. ravenelii* B. et C.
94. *B. retipes* B. et C.
95. *B. speciosus* Frost.
96. *B. subtomentosus* Linn.
97. *B. variegatus* Swartz.
98. *Strobilomyces strobilaceus* (Scop.) Berk.
99. *Boletinus decipiens* (B. et C.) Pk.
100. *Fistulina hepatica* Fr.
101. *Polyporus borealis* (Wahlenb.) Fr.
102. *P. dichrous* Fr.
103. *P. elegans* (Bull.) Fr.
104. *P. elegans* var nummularius (Fr.) Sacc.
105. *P. epileucus* Fr.
106. *P. flavo-virens* B. et Rav.
107. *P. fumosus* (Pers.) Fr.
108. *P. hirsutulus* Schwein.
109. *P. nivosus* Berk.
110. *P. sulphureus* (Bull.) Fr.
111. *Fomes applanatus* (Pers.) Wallr.
112. *F. carneus* Nees.
113. *F. curtisii* Berk.

114. *F. fuliginosus* Fr.
115. *F. salicinus* (Pers.) Fr.
116. *Polystictus abietinus* Fr.
117. *P. circinatus* Fr.
118. *P. decipiens* Schwein.
119. *P. lutescens* Pers.
120. *P. montagnei* Fr.
121. *P. parvulus* Klotzsch.
122. *P. pergamenus* Fr.
123. *P. perennis* (Linn.) Fr.
124. *P. sanguineus* (Linn.) Mey.
125. *P. tomentosus* Fr.
126. *P. versicolor* (Linn.) Fr.
127. *Cyclomyces greenii* Berk.
128. *Favolus canadensis* Klotzsch.
129. *F. tessellatus* Mont.

FAMILY HYDNACEÆ.

130. *Hydnum aurantiacum* Alb. et Schwein.
131. *H. adustum* Schwein.
132. *H. candidum* Schmidt.
133. *H. fragile* Fr.
134. *H. glabrescens* B. et Rav.
135. *H. gracile* Fr.
136. *H. graveolens* Delast.
137. *H. levigatum* Swartz.
138. *H. pulcherrimum* B. et C.
139. *H. repandum* Linn.
140. *H. rufescens* Pers.
141. *H. squamosum* Schæff.
142. *H. zonatum* Batsch.
143. *H. velutinum* Fr.
144. *Tremellodon gelatinosum* (Scop.) Pers.
145. *Radulum pallidum* B. et C.

FAMILY THELEPHOREÆ.

146. *Craterellus cantherellus* (Schwein.) Fr.
147. *C. cornucopioides* (Linn.) Pers.
148. *C. odoratus* Schwein.
149. *Thelephora anthocephala* Fr.
150. *T. cæspitulans* Schwein.
151. *T. cladonia* Schwein.
152. *T. dissecta* Lév.
153. *T. schweinitzii* Pk.
154. *T. sebacea* Pers.
155. *T. spectabilis* Lév.
156. *Stereum frustulosum* (Pers.) Fr.
157. *S. spadiceum* Fr.
158. *S. subpileatum* B. et C.
159. *S. versicolor* (Swartz) Fr.
160. *Hymenochæte rubiginosa* (Schr.) Lév.
161. *H. tabacina* (Sow.) Lév.
162. *H. umbrina* B. et C.
163. *Exobasidium rhododendri* Cramer. On leaves of Rhododendron maximum.

FAMILY CLAVARIACEÆ.

164. *Clavaria abietina* Pers.
165. *C. cinerea* Bull.
166. *C. cristata* Pers.
167. *C. flava* Schæff.
168. *C. fusiformis* Sowerb.
169. *C. gracilis* Pers.
170. *C. gracillima* Pk.
171. *C. grisea* Pers.
172. *C. petersii* B. et C.
173. *C. pinophila* Pk.
174. *C. tetragona* Schwein.
175. *Pterula densissima* B. et C.
176. *Typhula muscicola* (Pers.) Fr.

FAMILY TREMELLACEÆ.

177. *Dacryomyces chrysocoma* (Bull.) Tul.
178. *D. involutus* Schwein.
179. *Guepinia spathularia* (Schwein.) Fr.
180. *Hormomyces fragiformis* Cke.

ORDER GASTEROMYCETEÆ.

FAMILY PHALLACEÆ.

181. *Ithyphallus impudicus* (Linn.) Fr.

FAMILY NIDULARIACEÆ.

182. *Cyathus stercoreus* (Schwein.) De Ton.
183. *C. striatus* (Huds.) Hoffm.
184. *Crucibulum vulgare* Tul.

FAMILY LYCOPERDACEÆ.

185. *Mitremyces lutescens* Schwein.
186. *Bovista pila* B. et C.
187. *Lycoperdon calyptriforme* Berk.
188. *L. echinatum* Pk.
189. *L. gemmatum* Batsch.
190. *L. muscorum* Morg.
191. *L. perlatum* (Pers.) Fr.
192. *L. subincarnatum* Pk.
193. *L. turneri* E. et E.
194. *Scleroderma lycoperdoides* Schwein.
195. *S. verrucosum* (Bull.) Pers.
196. *S. vulgare* Hornem.

ORDER UREDINEÆ.

197. *Puccinia circææ* Pers. On Circæa alpina.
198. *P. menthæ* Pers. On Labiate species.
199. *P. tenuis* Burrill. On Eupatorium.

ORDER PHYCOMYCETEÆ

FAMILY PERONOSPORACEÆ.

200. *Plasmopara viticola* (B. et C.) Berl. et De Ton.

ORDER PYRENOMYCETEÆ.

FAMILY PERISPORIACEÆ.

201. *Microsphæra alni* (DC.) Winter. On Castanea vesca and Corylus americana.

202. *M. grossulariæ* (Wallr.) Lév.=*M. vanbruntiana* Ger. On Sambucus canadensis.

203. *M. vaccinii* C. & P. On Vaccinium.

204. *Podosphæra biuncinata* C. & P. On Hamamelis virginica.

205. *P. oxyacanthæ* (DC.) D. By. On Cratægus punctata.

FAMILY SPHÆRIACEÆ.

206. *Hypoxylon petersii* B. & C.

207. *Daldinia vernicosa* (Schwein.) Ces. et D. Not.

208. *Xylaria carniformis* Fr.

209. *X. cornu-damæ* (Schwein.) Berk.

210. *Ustulina vulgaris* Tul.

FAMILY HYPOCREACEÆ.

211. *Cordyceps militaris* (L.) Link.

212. *C. ophioglossoides* (Ehr.) Link.

213. *Hypomyces banningii* Pk. On Lactarius.

214. *H. lactifluorum* (Schwein.) Tul. On Lactarius piperatus.

215. *H. viridis* (Alb. et Schwein.) Karst. On undetermined agaric.

ORDER DISCOMYCETEÆ.

FAMILY HELVELLEÆ.

216. *Helvella macropus* (Pers.) Karst.

217. *Mitrula lutescens* B. et C.

218. *Geoglossum hirsutum* Pers.
219. *G. Walteri* Berk.
220. *Spathularia velutipes* Cke. et Farlow.

FAMILY PEZIZEÆ.

221. *Geopyxis pallidula* C. et Pk.
222. *Otidea onotica* (Pers.) Fuck.
223. *Lachnea cubensis* B. et C.
224. *L. fusicarpa* Ger.
225. *L. hirta* Schum.
226. *L. theleboloides* Alb. et Schwein.
227. *Helotium citrinum* (Hedw.) Fr.
228. *H. epiphyllum* (Pers.) Fr.
229. *Phialea scutula* (Pers.) Gill.
230. *Chlorosplenium æruginosum* (Œder.) De Not.
231. *C. tortum* (Schwein.) Fr.
232. *Phæopiza scabrosa* (Cke.) Sacc.

FAMILY BULGARIEÆ.

233. *Leotia chlorocephala* Schwein.
234. *L. lubricata* (Scop.) Pers.
235. *Ombrophila clavus* (Alb. et Schwein.) Cke.
236. *Calloria xanthostigma* (Fr.) Phill.
237. *Bulgaria inquinans* (Pers.) Fr.

ORDER MYXOMYCETEÆ.

238. *Arcyria punicea* Pers.
239. *Didymium farinaceum* Schrad.
240. *D. squamulosum* (Alb. et Schwein.) Fr.
241. *Fuligo septica* (Link) Gmel.
242. *Hemiarcyria varneyi* Rex.
243. *Leocarpus fragilis* (Dicks.) Rost.
244. *Stemonitis ferruginea* Ehrh.
245. *S. maxima* Schwein.
246. *Tilmadoche nutans* (Pers.) Rost.
247. *Trichia chrysosperma* (Bull.) DC.

ORDER HYPHOMYCETEÆ.

248. *Isaria farinosa* Fr.
249. *I. tenuipes* Pk.
250. *Zygodesmus fuscus* Corda.

ORDER SPHÆROPSIDEÆ.

251. *Phyllosticta violæ* Desm.

ORDER MELANCONINEÆ.

252 *Pestolozzia funerea* var *multiseta* Desm.

ORDER SACCHAROMYCETACEÆ.

253. *Saccharomyces pyriformis* Ward.

ORDER SCHIZOMYCETACEÆ.

254. *Bacterium vermiforme* Ward.

BOTANICAL DEPARTMENT, CORNELL UNIVERSITY.
March 12, 1893.

RECORD OF MEETINGS.

SEVENTIETH MEETING.

GERRARD HALL, September 13, 1892.

Southern Industrial Progress. Dr. William B. Phillips.

SEVENTY-FIRST MEETING.

PERSON HALL, October 18, 1892.

10. The Work of Science. Charles Baskerville.
11. Early Manufacture of Iron in North Carolina. H. B. C. Nitze.
12. Encystment of Earth-worms. H. V. Wilson.
13. Experiments on Halving Eggs. H. V. Wilson.
14. Effect of the Earth's Rotation on the Deflection of Streams. Collier Cobb.
15. Note on Traps and Sandstone in the Neighborhood of Chapel Hill. Collier Cobb.

SEVENTY-SECOND MEETING.

PERSON HALL, November 15, 1892.

16. A New Secondary Cell. J. W. Gore.

17. Some Curious Products from the Willson Aluminum Works. F. P. Venable.

18. On the Production of an Animal Without Any Maternal Characteristics. H. V. Wilson.

SEVENTY-THIRD MEETING.

PERSON HALL, December 6, 1892.

19. Work of the N. C. Geological Survey. J. A. Holmes.

20. Cerebral Localization. R. H. Whitehead.

The following officers were elected for 1893:

President	PROF. J. A. HOLMES	Chapel Hill.
First Vice-President	PROF. H. L. SMITH	Davidson.
Second Vice-President	PROF. J. W. GORE	Chapel Hill.
Librarian	PROF. COLLIER COBB	Chapel Hill.
Secretary and Treasurer	PROF. F. P. VENABLE	Chapel Hill.

The Secretary reported 1,170 books and pamphlets received during the year, making the total number 9,948.

Two new members were also reported: Prof. Stedman, Trinity College; Prof. Bandy, Trinity College.

REPORT OF TREASURER FOR 1892.

By balance from 1891	$ 40 02	
By fees for 1892	64 50	
By contributions	100 00	
By sales of Journals	1 50	
	$206 02	
To postage		$ 15 65
To engraving		10 82
To express		2 75
To printing		193 00
		$222 22
Deficit		$ 15 80

JOURNAL

OF THE

Elisha Mitchell Scientific Society,

1891

EIGHTH YEAR. PART ONE.

JOURNAL

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EIGHTH YEAR. PART SECOND.

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NINTH YEAR. FIRST PART.

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NINTH YEAR. SECOND PART.